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The country data, available in the form of statistical tables or maps, have been the main source of information for the global forest resources assessment and the direct determinant of its quality and content. So far a statistically designed pan-tropical forest survey has not been attempted. Therefore, a review of the current state of the country forest inventories (see Annex 1) is an appropriate starting point for discussion of the Project methodology.

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Source: FORIS database of the Project

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Forest resources assessment 1990

Tropical countries

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PREFACE

Governments, the general public and the international community at large have manifested increasing uneasiness over the clearing and degradation of forests all over the world. By devoting a significant part of its debate and decisions to issues of forest conservation and development, the United Nations Conference on Environment and Development (UNCED, Rio, June 1992) has amply reflected this unprecedented concern for the fate of the world's forests.

However there cannot be sound decisions and action in the management of forests at any level, whether local or global, without reliable information on their situation and evolution over time. Such information is indispensable whatever the objective of management of forests, be it fuelwood production at local level, timber production for export, conservation of biodiversity or mitigation of climate change at global level. Thus in Chapter 11 of UNCED Agenda 21 titled "Combatting deforestation", the assessment and systematic observation of forest resources is a key element in one of the four programme areas.

In pursuance of its mandate, FAO has undertaken periodic assessments of the world's forest resources, of which the first was nearly 50 years ago in 1946 and the last in 1980. The 1990 Global Forest Resources Assessment builds upon the 1980 study. It has three components: (a) the assessment for the tropical countries which is presented in this report; (b) the assessment of the forest resources of the industrialised countries which has been carried out and published recently jointly by FAO and the Economic Commission for Europe of the United Nations; and (c) the assessment for the non-tropical developing countries which is to be published in early 1994.

This report provides comprehensive information on the current state of tropical forests including deforestation, management, conservation and development of the resource. It addresses for the first time issues related to forest degradation, loss of biomass and biodiversity. New methodology has been developed for more accurate estimation of changes. The core of this methodology is the ability to analyse forest resource data in the form of time series. Both data which were available with member countries and new data obtained from satellite remote sensing images have been used for this purpose.

Classifications and definitions used in forest inventories often differ from country to country, since they are designed to satisfy specific national or local needs. To arrive at a common classification, format and reference date, original data provided by countries had to be reorganised. It must be stressed, however, that the standardised country results in this international report are intended only to secure a consistent global picture; they do not replace the original country statistics which will remain a unique source of reference.

The 1990 assessment has been a key activity under the FAO Regular Programme, carried out with substantial support from donor countries. Its implementation has benefited greatly from ready cooperation of all countries which are reported upon here, as well as the technical contributions made by many scientific institutions and individuals. This report also reflects the dedication of Forest Resources Assessment 1990 Project staff.

This assessment is intended to satisfy most of the urgent information needs of policy makers, the scientific community and the general public. However, the exercise has revealed a need to fill certain gaps in knowledge and to improve national capacities to carry out their own forest resources assessments. FAO intends to give greater attention to these aspects in future and to make the assessment a continuous and adaptable process.

C.H. Murray
Assistant Director-General
Forestry Department

ACKNOWLEDGEMENTS

The Forest Resources Assessment 1990 was supported by the Governments of Finland, France, Italy, the Netherlands, Sweden and Switzerland through a multi-donor trust fund. Major in-kind contributions were made by the Swedish University of Agricultural Sciences, the United States Forest Service and the World Conservation Monitoring Centre (Cambridge, United Kingdom). Personnel assistance was given through the Associate Professional Officers scheme of the Governments of Belgium, Germany, the Netherlands, Sweden and the United States of America. Member countries have contributed by sending source information, by cooperating in the interpretation of remote sensing data and by reviewing the compilations made by FAO. The assessment was conducted by a project team coordinated by Dr. K.D. Singh at FAO, Rome. The Food and Agriculture Organization is greatly indebted to all those who assisted in the implementation of the project by providing information, advice, facilities and funds.

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ABBREVIATIONS

AVHRR	Advanced Very High Resolution Radiometer
BIBLIO	Bibliography Documentation Programme
ECE	Economic Commission for Europe
ECR	Edge/core Ratio
EFZ	Ecofloristic Zone
FAO	Food and Agriculture Organization of the United Nations
FINNIDA	Finnish International Development Authority
FORIS 1990	Forest Resources Information System 1990
FRA 1990	Forest Resources Assessment 1990 Project
GIS	Geographic Information System(s)
IBAMA	Instituto Brasileiro do Meio Ambiente y dos Recursos Naturais Renovaveis (Brazil)
IGADD	Intergovernmental Authority on Drought and Development
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
ITTO	International Tropical Timber Organization
IUCN	International Union for the Conservation of Nature (The World Conservation Union)
LANDSAT MSS/TM	LANDSAT Satellite Multi-spectral Scanner/Thematic Mapper
NASA	National Aeronautics and Space Administration (United States of America)
NOAA	National Oceanic and Atmospheric Administration
PAI	Perimeter Area Index
PC	Personal Computer
TCDC	Technical Cooperation among Developing Countries
TFAP	Tropical Forests Action Programme
UNCED	United Nations Conference on Environment and Development (Rio de Janeiro, Brazil, June 1992)
UNDP	United Nations Development Programme
UNEP-GRID	United Nations Environment Programme - Global Resources Information Database
USDA	United States Department of Agriculture
USGS/EROS	United States Geological Survey/Earth Resources Observation Satellite
WCMC	World Conservation Monitoring Centre

SUMMARY

The main objectives of the present assessment were: (i) to provide reliable and globally consistent information on the state of the tropical forests by 1990 and the rates of change during 1981 to 1990 and (ii) to undertake studies on the process of deforestation and forest degradation and their environmental implications.

The assessment covering 90 countries was carried out in two phases. The available statistical information on forest cover area, growing stock, management, conservation and utilisation of forests was first compiled and incorporated into a database. The spatial information on vegetation cover, ecological zones and administrative boundaries at subnational level was scanned, edited and integrated with the statistical data in the form of a geographic information system. The collected data were used to build a deforestation model, to estimate forest cover area at end 1990 and rates of change during 1981 to 1990.

In addition, a remote sensing based survey of the tropical forests using high resolution satellite data of two dates, one close to 1980 and the other close to 1990, was implemented at 117 sample locations. State and change information was interpreted and stored in the form of change matrices following the standard procedure developed. These data were analysed to obtain in-depth knowledge of the process of deforestation and forest degradation on the sample locations, by geographic subregion and ecological zone. Results for Africa are presented as an example.

The **pan-tropical forest cover** was 1,756 million ha at end 1990 and 1,910 million ha at end 1980 (this latter figure replaces the earlier estimate of 1,935 million ha provided by the 1980 FAO/UNEP Tropical Forest Resources Assessment project). Thus, average annual deforestation during the past decade amounts to 15.4 million ha (0.8 percent in compound annual rate of deforestation). The largest extent of forest cover was in Latin America and Caribbean (918 million ha: 52 percent of the total tropical forest area), followed by Africa (528 million ha: 30 percent), and Asia and Pacific (311 million ha: 18 percent). The annual loss of forest cover by region was: Latin America and Caribbean 7.4 million ha (0.8 percent), Asia and Pacific 3.9 million ha (1.2 percent) and Africa 4.1 million ha (0.7 percent).

At end 1990 lowland formations were 1,544 millon ha (88 percent of the total tropical forest area) and upland (hill and montane) formations 204 million ha (12 percent). Among the lowland formations, the tropical rainforests constituted the biggest portion, namely 718 million ha (or 41 percent), the moist deciduous forests 587 million ha (33 percent) and the dry and very dry zone forests 238 million ha (14 percent). The rest of the forests, nearly 8 million ha, were scattered in the non-forest zone. The annual loss of forest cover by ecological zone were: the tropical rainforests 4.6 million ha (0.6 percent), the moist deciduous forests 6.1 million ha (1.0 percent), the dry and very dry zone forests 2.2 million ha (0.9 percent) and the upland formations 2.5 million ha (1.1 percent).

Comparing the forest area to the land area ratio for each ecological zone, it appears that 76 percent of the tropical rainforest zone is still covered with forest. As can be expected, the percentage of the forest cover declines with drier conditions and differences are quite obvious: 46 percent are forested in the moist deciduous, 30 percent in the dry deciduous and 19 percent for the dry and very dry zones together. One can assume that in the very dry zone the original forest area was considerably less than 100 percent of the total land area. This is in contrast to the rainforest and moist zones where the original forest area was close to 100 percent.

During 1961 to 1990 a steadily rising trend was observed regarding the area harvested for production of non-coniferous industrial roundwood in all three tropical regions, but little progress seems to have been made in the sustainable management of the natural forests.

The assessment results also indicate that 14 percent of the land area is set apart in the tropical zone for conservation purposes of which 3.8 percent is under total protection

The reported area of forest plantations in the tropics at end 1990 was 43.9 million ha and the net area (after deduction of mortality and failures) 30.7 million ha (namely 70 percent). During 1981 to 1990 the reported forest plantations area increased annually on average by 2.6 million ha and the net area by 1.8 million ha. Thus, the net area planted per annum was about 12 percent of the area deforested every year.

The special studies made by the Project show that forest fragmentation, biomass and biodiversity loss are important processes associated with deforestation and forest degradation in the tropics.

The work has clearly revealed that a great majority of the tropical countries have insufficient institutional capacity to collect and analyse data on a continuous basis. This finding has been highlighted by UNCED and confirms the need to include "establishing and/or strengthening capacities for the planning, assessment and systematic observation of forests" as a fully fledged programme area in Agenda 21.

Chapter I

BACKGROUND

1. INTRODUCTION

Since the first United Nations Conference on Human Environment in Stockholm (1972), forests in general, and tropical forests in particular, have been receiving increasing attention from the world community. A high point was reached at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro (1992) which devoted a full chapter of its Agenda 21 (entitled "Combating deforestation") to forest conservation and development and adopted the "non-legally binding, authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests".

A major contributory factor to this concern for the current state of tropical forests has been the large degree of uncertainty associated with the information on rate of deforestation. Several related questions have been posed by policy-makers, the scientific community and the public at large. What is the area of the remaining tropical forests? At what rate are they being depleted? Is the rate of deforestation accelerating or slowing down? What are the causes? What are the ecological, economic and social impacts? And so on.

The FAO/UNEP Tropical Forest Resources Assessment completed in 1982 provided an answer to some of these questions. However, as time passed, the figures became out of date and the concern grew. There were also new issues, different from those of the 1980s: questions about global climate change, loss of biodiversity, etc. which demanded increased precision of estimates and new types of information. Forests could be a source or a sink of global carbon depending on whether there was an increase or decrease in forest biomass; a question closely related to tropical deforestation. Loss of biodiversity and land degradation were other problems for which no reliable assessment methodology or data existed.

These issues called for a new generation of global assessments. There were five main requirements for the technique to be developed to estimate the rate of deforestation:

(i) The database used should be verifiable and the procedures of assessment objective.

(ii) The technique should have a statistical basis and provide not only mean values but also their confidence limits (e.g. mean deforestation rate and its standard error).

(iii) The procedure must provide consistent and comparable estimates over time, because deforestation is a dynamic process.

(iv) The approach must address causes and impacts of deforestation, as these have become important issues in view of global concern about the possible effects of deforestation and forest degradation on the CO_2 cycle, loss of biodiversity, land degradation, etc.

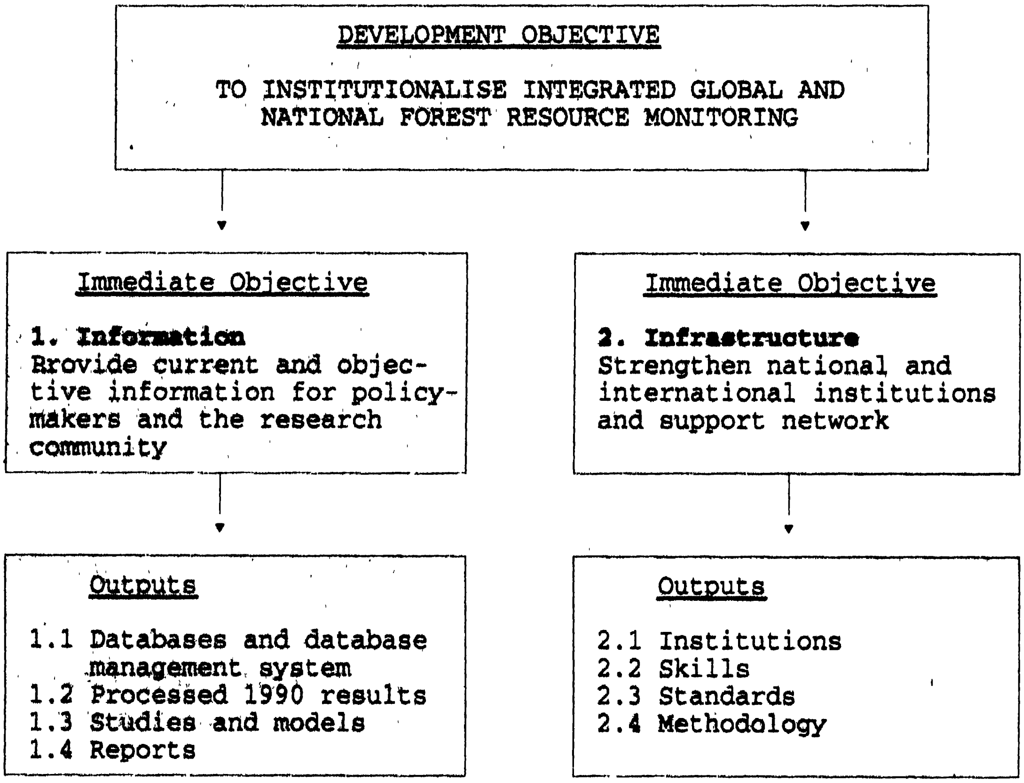
(v) The methodology must be easily transferable to member countries. This would contribute to the development of sound programmes for national forest resources assessment from which the global assessments could benefit.

As is clear from the above, the assessment was expected to be implemented on a statistically sound basis, not only to provide reliable results but also to **provide a time-series of estimates**, of known precision, and to contribute to **knowledge about the process** of deforestation. It may be noted that consistency and continuity of assessment have implications for **continuity of institutions** at the global and national levels.

2. OBJECTIVES OF ASSESSMENT

Figure 1 schematically presents the development and immediate objectives with associated outputs of the assessment.

Figure 1
Objectives and outputs of the Forest Resources Assessment 1990



DEVELOPMENT OBJECTIVE

TO INSTITUTIONALISE INTEGRATED GLOBAL AND NATIONAL FOREST RESOURCE MONITORING

Immediate Objective

1. Information
Provide current and objective information for policy-makers and the research community

Immediate Objective

2. Infrastructure
Strengthen national and international institutions and support network

Outputs

1.1 Databases and database management system
1.2 Processed 1990 results
1.3 Studies and models
1.4 Reports

Outputs

2.1 Institutions
2.2 Skills
2.3 Standards
2.4 Methodology

The development goals of the Forest Resources Assessment 1990 were to:

(i) assist member countries and the world community in reviewing policies, promoting cooperation and taking appropriate action for conservation, development and management of tropical forest resources;

(ii) support studies of a regional and international nature requiring country forest resource information in a common and harmonised format;

(iii) develop national capabilities for periodic assessment and monitoring of forest resources.

The immediate objectives were to:

(i) make an assessment of the forest resources of the tropical countries for the reference year 1990, and estimate the changes that have taken place during 1981 to 1990;

(ii) prepare vegetation and ecofloristic zone maps, and integrate these with socio-economic data, the FAO soil map and the protected area map of IUCN/WCMC in the form of a GIS;

(iii) study the environmental impact of deforestation and forest degradation in the tropics;

(iv) disseminate the database and the methodology of assessment to the national and international institutions.

Objectives (i) and (ii) concern the building of an **information base**; objective (iii) concerns the building of a **knowledge base** on deforestation; and objective (iv) concerns the building of an national **institution base** for present and future forest resources assessment.

3. PROJECT IMPLEMENTATION

The Eighth Session of the Committee on Forestry (COFO) held in Rome, 21-25 April 1986, recommended the "strengthening of FAO's programme of collection, evaluation and dissemination of information related to forest resources and resource development" (paragraph 14) and "updating of information on tropical deforestation in order to provide reliable baseline data" (paragraph 45). These recommendations were endorsed by the FAO Council at the Nineteenth Session in Rome, November 1986.

The preparations for the new assessment were initiated by FAO Forestry Department in 1987. The FAO/ECE/Finland "Ad Hoc Meeting on World Forest Resources Assessment" was held at Kotka, Finland, October 1987. Forty experts took part in the meeting: 20 from developing, and 20 from developed countries, representing a cross-section of expertise. Four major areas for assessment were identified by the group including the need for:

(i) estimation of the current state of forest cover and its rates of change;

(ii) estimation of volume and biomass;

(iii) information on forest management, logging, forest plantations, etc. and

(iv) establishment of a GIS database to assess environmental impacts and service functions of forests.

The FAO Forestry Department, responding to the recommendations of its statutory bodies, prepared an umbrella document for implementing the new round of global forest resource assessment to update the 1980 assessment and submitted part of it to donors for funding consideration. The proposal consisted of three components, including assessments of: (i) the tropical zone; (ii) the subtropical zone; and finally (iii) a global synthesis. The data for the temperate and boreal forests were to be provided by the FAO/ECE Agriculture and Timber Division, Geneva. The data for the tropical and subtropical components were to be provided by FAO Forestry Department, Rome.

The tropical component of the Forest Resources Assessment 1990 Project (hereafter also called the Project) became operational on 1 March 1989 with the initial funding from Sweden, the Netherlands and France. Two special studies were subsequently added to this, namely application of remote sensing funded by Finland and of GIS funded by Switzerland. Sweden provided a second contribution to support research, training and technology transfer, the United States of America provided support for GIS and training and Italy provided support for strengthening the database of the IGADD subregion of Africa.

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- There is considerable variation in the timeliness of the information. The data is about ten years old, on average, which could be a potential source of bias in the assessment of change.

- There are some countries which have carried out more than one assessment. These countries, however, have not used appropriate techniques, such as Continuous Forest Inventory (CFI) design, for change assessment.

- Only a few countries have reliable estimates of actual plantations, harvest and utilisation although such estimates are essential for national forestry planning and policy-making.

- No country has carried out a national forest inventory containing information that can be used to generate reliable estimates of the total woody biomass volume and change.

- It is unlikely that the state and change information on forest cover area and biomass could be made available on a statistically reliable basis at the regional or global levels within the next ten or twenty years unless a concerted effort is made to enhance the country capacity in forest inventory and monitoring.

The above findings establish that forest resource assessments are among the most neglected aspects of forest resource management, conservation and development in the tropics.

2. REVIEW OF APPROACHES TO ASSESSMENT

Two main techniques of global assessments have been tried so far based on the country data: (i) a questionnaire approach and (ii) a centralised assessment approach. The questionnaire approach was started in 1948 and discontinued in 1965 because of many non- or incorrect responses. A centralised assessment was started by FAO/UNEP Tropical Forest Resources Assessment Project (1980) by collecting the existing country data from a wide variety of sources at FAO HQ, Rome, bringing them to a common conceptual and mensurational standard and adjusting results to the common reference year 1980 using an empirical approach.

The expert consultation held at Kotka Finland in 1987 recommended that the present Project follow the approach of the FAO/UNEP 1980 assessment for estimating the forest cover area at end 1990 and then estimate the change by taking the difference between the 1990 and 1980 figures. However, the first results of the Project demonstrated clearly that this approach is not suitable for the change estimation because the resulting estimate of change had high variance, being the sum of the variance of 1980 and 1990 estimates according to the law of propagation of errors. The following remarks clarify this point further.

It may be noted that at the time of the FAO/UNEP 1980 assessment:

- forest cover information was available for only 23 countries. To alleviate the situation, the FAO/UNEP Project carried out area assessment for 13 countries by interpreting Landsat MSS images at 1:1 million scale;

- the average date of the country information lagged substantially behind the global assessment year being 1980, requiring extrapolation to bring country data to a common reference date;

- very few countries had more than one assessment of forest cover. Therefore, the only way to adjust results to the standard year was through an empirical process.

The situation for the FAO 1990 assessment was as follows.

- All countries (except three in Africa) possessed one estimate of forest cover made during 1970 to 1990, mostly based on remote sensing.

- The variations in the date of the country data were still a major problem. It has been found that the average age of country data available for the 1990 assessment is, in fact, close to 1980.

- Twenty-one countries had carried out more than one forest cover assessment.

- There had been substantial developments in technology, in particular geographic information system (GIS), remote sensing and modelling techniques.

Another limitation associated with the recommended approach lies in the fact that the least precise of the two constituent assessments is the determinant of the variance of the estimate. Therefore, improved coverage, timeliness and reliability of the country data during 1980 to 1990 make little or no impact on the precision of change estimate.

Error Propagation in Change Estimation from Independent Surveys

Let f_1 and f_2 denote estimates of forest cover areas for two points of time, here 1980 and 1990 respectively; $V(f_1)$ and $V(f_2)$ denote the respective variance. If the two assessments are **independently conducted**, then the change is estimated by $(f_1 - f_2)$ and its variance by:

$$V(f_1 - f_2) = V(f_1) + V(f_2)$$

The above formulation clearly shows that the variance of change estimate is jointly determined by the variance of the two contributing assessments. If one of them has low value and the other high value, then the variance of difference will be high, irrespective of the low value of one of them.

In Chapter 1 mention was made of the high expectations of the world community from the FRA 1990, whereas the review of the current state of forest inventory revealed major gaps in conducting a global assessment based on country data. The challenge was to produce the expected results making the best use of available data, appropriate techniques and new technology (remote sensing, GIS, computerised database management and modelling techniques). The Project, with the support of the cooperating institutions, set towards developing an approach which could fulfill many of the requirements listed earlier. The following are highlights of the tools and techniques investigated and applied.

(i) Use of a database management system for easy storage, retrieval, analysis and updating of information.

(ii) Introduction of a modelling technique to estimate deforestation objectively.

(iii) Use of auxiliary variables, dynamic in nature, such as population density and population growth, for which data is readily available and which are among the important driving forces behind deforestation.

(iv) Reduction in size of the assessment unit from national to subnational level which is ecologically and demographically more homogeneous.

(v) Use of variance-reducing techniques while making estimation, such as stratification of the subnational units by ecological criteria.

(vi) Use of multi-date high resolution satellite data to estimate changes on an objective and statistically sound basis.

Continuous Forest Inventory Design

Using the continuous forest inventory (CFI) concept, it is possible to significantly reduce the error term. In this class of designs, the source data of surveys at two points of time are not independently but inter-dependently analysed. Assuming a design in which all units are measured on two dates, the error term associated with change would have the following value:

$$V(f_1 - f_2) = V(f_1) + V(f_2) - 2\,Cov(f_1, f_2)$$

where $V(f_1)$ and $V(f_2)$ are variances of the forest cover observations on the same area unit on two dates and $Cov(f_1,f_2)$ is the co-variance between them. If $V(f_1) = V(f_2)$ and $Cov(f_1,f_2) = 0.8\ V(f_1)$, which are reasonable assumptions, the variance of the difference in the case of inter-dependent assessment will be only one-fifth of the that associated with independent assessments.

Working on the above ideas, the Project developed and put into operation a design which consisted of the following two phases:

(i) A "model" approach using the existing country information, both in tabular and spatial form (i.e. in the form of maps). This low-budget technique is cost-effective and provides efficient country estimates, but is not able to satisfy completely all the five concerns listed in the introductory chapter, particularly at the regional and global levels.

(ii) A "survey" approach using multi-date high resolution satellite data. This technique satisfies rather well all the five requirements listed in Section 1 of Chapter I with reference to regional and global levels.

To add to the benefit, the two phases were integrated in the framework of a statistical design. The following chapter will report on the methodology and main results of the two phases.

Chapter III

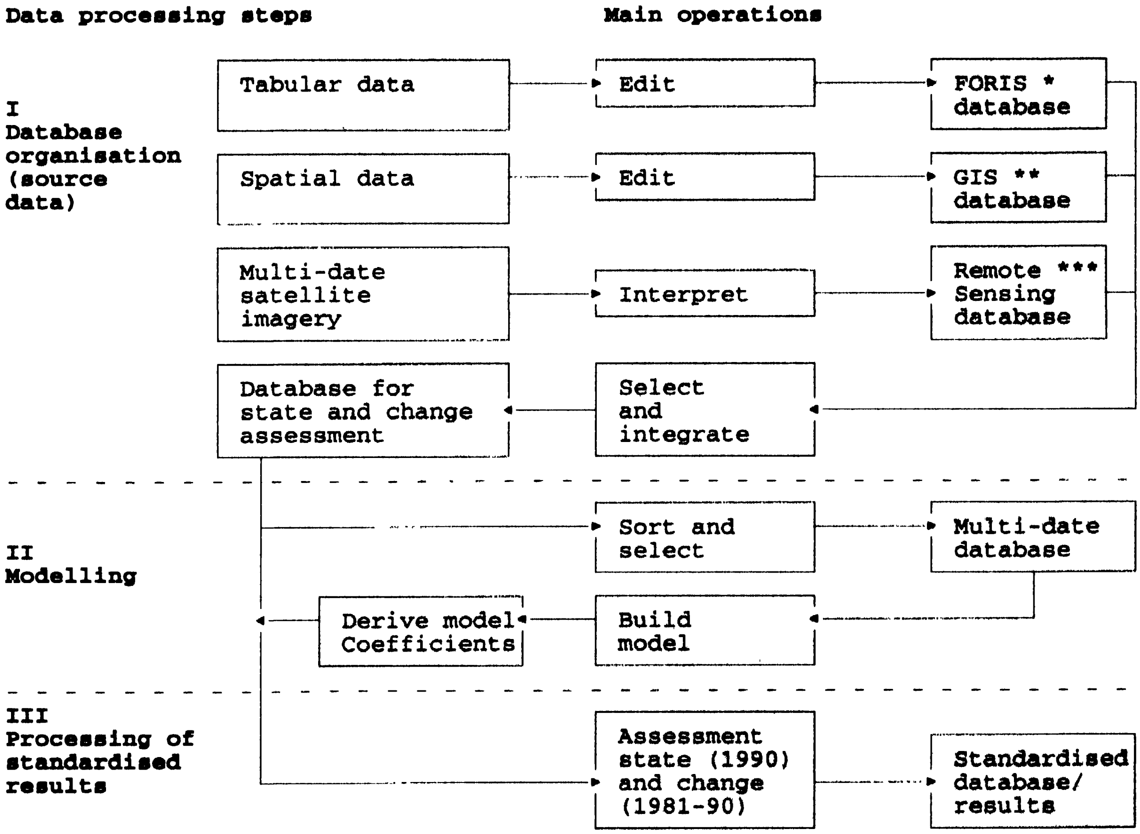
METHODOLOGY

1. FOREST COVER STATE AND CHANGE ASSESSMENT

The technique of assessment is presented in the form of a flow chart in Figure 2. It consists of the following three steps: (i) establishment of a computerised database; (ii) development of deforestation model (or an adjustment function); and (iii) computation of results for the standard reference years.

Figure 2
Forest cover state and change assessment (using existing reliable data)

Objectives: Produce standardised data relating to:
- 1990 forest cover area
- 1981-1990 forest cover area change


Data processing steps
Main operations
I
Database organisation (source data)
Tabular data
Edit
FORIS *
database
Spatial data
Edit
GIS **
database
Multi-date satellite imagery
Interpret
Remote ***
Sensing
database
Database for state and change assessment
Select and integrate
II
Modelling
Sort and select
Multi-date database
Derive model Coefficients
Build model
III
Processing of standardised results
Assessment state (1990) and change (1981-90)
Standardised database/ results

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* FORIS is the acronym for Forest Resources Information System. It is a computerised database to store/retrieve national/sub-national forest resource information

** GIS stands for Geographic Information System used to store spatial/cartographic and related statistical data

*** Multi-date remote sensing data was used in the model for the Africa region as existing data was not considered adequate.

1.1 Establishment of a database

The data compiled by the Project consists of two categories:

(i) **Tabular data** including forest resources, population and socio-economic data at the subnational level (province, state).

The *Guidelines for assessment based on existing data* were prepared in the three official FAO languages to compile the country statistics and bring them in a framework of common concepts and classifications. Using the guidelines, the country reports were reviewed and reliable information extracted, edited and stored as part of the Project database with the acronym FORIS which stands for FOrest Resources Information System.

Terminology

Forests are defined as ecosystems with a minimum of 10 percent crown cover of trees and/or bamboos, generally associated with wild flora, fauna and natural soil conditions, and not subject to agricultural practices.

Deforestation refers to change of land use with depletion of tree crown cover to less than 10 percent. Changes within the forest class (from closed to open forest) which negatively affect the stand or site and, in particular, lower the production capacity, are termed *forest degradation*. Degradation is not reflected in the estimates.

FORIS is a database as well as a database management system. It runs in a PC environment using dBASE IV™. The data entering facility is user-friendly. Only minimum computer knowledge is required in order to enter, correct and print the data. FORIS is a useful database and database management system for planners and researchers.

(ii) **Map data** including vegetation types, ecofloristic zones and country and subnational boundaries

Realising that deforestation is a location-specific process driven by, among other things, population pressure and environmental conditions (particularly the population carrying capacity of the area), demographic and ecological parameters were included in the database and integrated with the statistical data in the form of a GIS. From the outset it was realised that a GIS was essential to handle statistical and spatial data from a variety of sources, in a variety of formats and in different projections. Therefore, GIS development was given special attention by the Project.

In the course of time, more spatial data were added to the Project GIS including LANDSAT 4.5 World Reference System Grid, potential global and forest biomass, mean annual precipitation and biotemperature, topography, protected areas, and vegetation map from NOAA/AVHRR satellite imagery (for some regions).

1.2 Deforestation model

The forest cover data contained in FORIS refer to different periods and need to be brought for reporting purposes to the standard years, namely 1980 and 1990. This was done with the help of a deforestation model (or a forest area adjustment function) which correlates forest cover change in time with other variables including population density and population growth for the corresponding period, initial forest cover area and the ecological zone under consideration. For developing the model only multi-date data at the subnational units are used and the function expressed in the form of a differential equation.

Deforestation Model

The model, expressed in the form of a differential equation, has the form:

$$\frac{dY}{dP} = b_1 * Y^{b_2} - b_3 * Y$$

where:

- Y is the percentage of non-forested area in a subnational unit computed as: Y = 100 * (Total area - Forest cover area)/(Total area)
- ,P = ln(1 + Population density) with population density expressed in persons per square kilometer (ln is the natural logarithm)

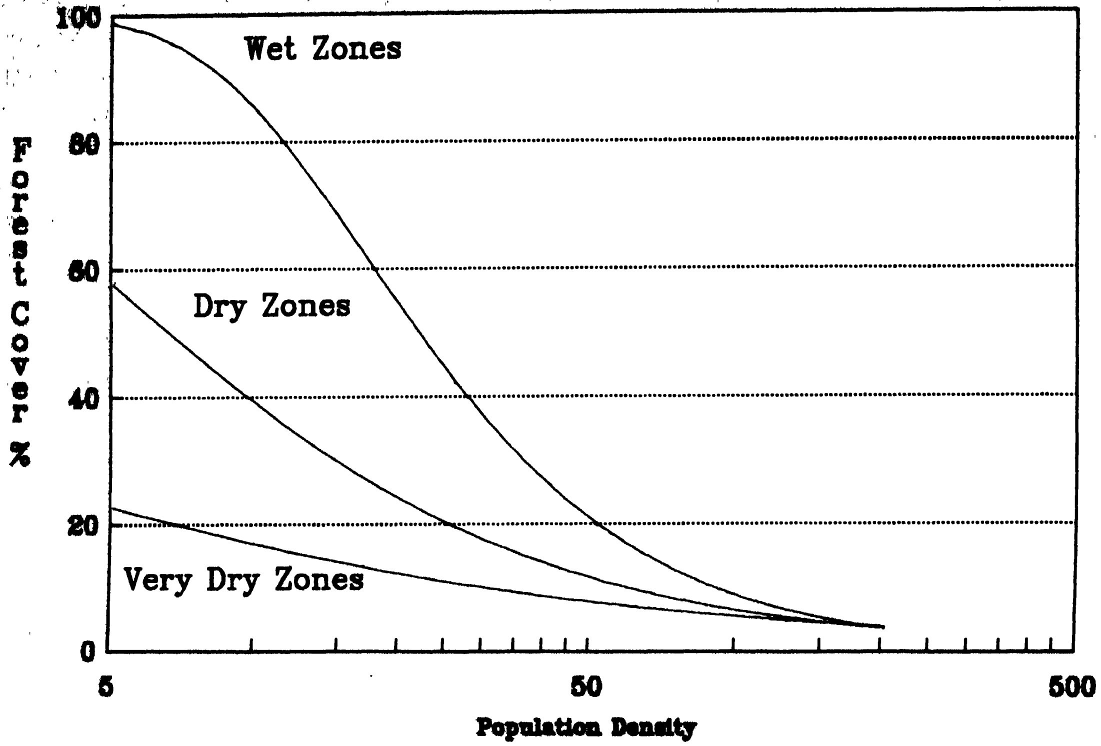
dY/dP is the derivative of Y with respect to P

- b_1, b_2 and b_3 are the model parameters.

The model interprets the human/forest interaction as a biological growth process. Very much like some biological growth processes, deforestation is observed to increase relatively slowly at initial stages, much faster at intermediate stages, and to slow down at final stages (see Figure 3).

Validation of the model was performed using a set of 16 observations not used to build the model, for which two or more reliable estimates of forest cover in time were available. The mean difference between the observed and the predicted changes was ± 10.6 percent. The residual distribution, despite some large deviations in the case of some subnational units, was quite symmetrical with no evidence of bias.

Figure 3
Illustration of model curves for different ecological zones



1.3 Assessment by geographic region

The FORIS database, in conjunction with the model, serves: (i) to adjust forest cover area data of the subnational units to the standard reference year 1990; and (ii) to produce estimates of the forest cover area change over the period 1981 to 1990. For these purposes the most recent forest inventory data of a national/subnational unit are used as baseline, and forest cover area in 1980 and 1990 (standardised results) computed according to one of the following options:

(i) Reliable multi-date inventories available; in this case the existing multi-date information is used to calibrate the general model with the 'local' b_1 parameter and the resulting model is then used to compute the standardised results. This is the optimum case.

(ii) Reliable single-date inventory available; in this case the standardised results are computed using the general model.

(iii) No reliable inventory available; in this case estimates of baseline forest cover area are extracted from calibrated vegetation maps existing in the projects' GIS and are then used as input to the modelling procedure described for option (ii).

The estimated values at subnational level are aggregated at national, regional and global levels. Keeping in view the law of propagation of errors the global estimates are expected to be more precise than the subregional; and the subregional estimates more precise than the national and subnational estimates.

For each option, procedures have been developed for integrating the FORIS and GIS data to compute the model parameters for each unit (subnational in most cases) and to provide forest cover in 1980 and 1990 as standardised output.

The model has proved to be a valid and flexible tool to estimate deforestation at a global level and to relate forest cover changes with demographic and ecologic variables. Given the scarcity of existing reliable multi-date observations, the model serves a very useful purpose in global forest resources assessment.

In the present system of assessment the up-dating of results is an almost continuous process. Both FORIS database and deforestation model parameters can be updated as and when additional country data become available. The addition of further records and fields in FORIS will improve the reliability of model parameters as well as precision of estimates for the country which in turn will improve the precision of the estimates at regional and global levels.

1.4 Assessment by ecological region

The environmental implications of deforestation and forest degradation are determined jointly by the type and magnitude of the human intervention as well as the ecological context of the land and forest area under change. Keeping this in view the Project developed a new system of global assessment whereby reports on the current state of forests and on-going changes are made by ecological region. As will be presented later, this type of assessment forms a basis of study on biodiversity loss at the ecosystem and species levels.

The ecological regions are defined with the help of ecofloristic zone (EFZ) map. The criteria applied in classifying ecofloristic zones are to begin with ecological: climatic, physiographic, and edaphic. Bioclimatic limits are determined based on parameters of mean annual rainfall, rainfall regime, length of the dry season, relative humidity and temperature. The physiographic contours, the soils and the leaf-retaining characteristics of the forest canopy (i.e. phenology) are used to further subdivide the bioclimatic zones. Within the ecological types thus defined, subtypes (syn. ecofloristic zones) are distinguished based on the dominant or characteristic woody species of the flora, with attention given to their successional positions. Thus, for each ecofloristic zone it is possible to define the vegetation types that it contains.

Vegetation types constitute another layer of important data for the state of forest ecosystem reporting. The vegetation classes are distinguished mainly by physiognomic criteria which can be seen in field and remote sensing documents, such as density, continuity of plant cover, height, etc, dense forests, secondary forests, woodlands, thickets, savannas, etc. are identified. The denomination of the formations is derived from the classification of Yangambi (1956) and of UNESCO (1973). These formations are further subdivided on the basis of density, ranging from the woody types that are the most closed, to the types that are the most open. This reflects the different stages of the regressive series or, in very rare cases, the evolutionary tendency of the vegetation within a zone.

Ecofloristic zones and vegetation types were mapped with consistent methodology across all regions, but have distinct legends. Separate maps exist for Africa, Continental South and Southeast Asia and South America.

The ecofloristic zone and vegetation maps are integrated with FORIS database to produce estimates of forest cover and change by ecological region.

A review of literature was made with a view to organising the existing knowledge on estimating biodiversity and its loss. The literature review suggested, as is well known, that the species distribution has a characteristic distribution pattern which is comparable within forests occurring in similar ecological regions. It was also observed that, within a given forest type, the number of species increases with the increase of forest area.

The main steps in estimating biodiversity loss were the following:

(i) Estimation of species richness in the inventoried areas, where reliable species identification has been done. This formed the main basis of species - area relation by main ecological region.

(ii) Estimation of loss of forest area by ecological region and its likely implication for the loss of species richness.

It need not be mentioned that the present state of knowledge does not permit making reliable statements on the extent and rate of loss of biodiversity.

2. FOREST BIOMASS STATE AND CHANGE ASSESSMENT

Forest biomass is the source of many products, including timber, fuel and fodder. Assessing the total aboveground biomass of forests (per unit area and for whole forested regions) is a useful step towards quantifying the amount of resource available for all these traditional purposes.

Terminology

Here biomass is defined as the total amount of above-ground organic matter present in trees (leaves, twigs, branches, main bole and bark), expressed either as oven-dry tons per hectare (referred to as biomass density) or as oven-dry tons per country, region, etc (referred to as total biomass). For most forests, this will include only the biomass in trees with diameters greater than 10 cm, however for forests of smaller stature, such as those in the dry tropical zones or degraded forests, the minimum diameter could be smaller than 5 cm. Furthermore, other forest components such as palms and bamboos are included only where they comprise an important component of the forest and local use. Not included are (1) undergrowth (except where important locally, see above) which is generally less than 5 percent of the aboveground biomass density, (2) forest floor fine litter, or (3) lying and standing dead wood.

Biomass of forests has become very relevant to studies related to global change. The biomass of forests provides estimates of the carbon pools in vegetation (about 50 percent of biomass is carbon) and consequently the potential amount of carbon dioxide that can be added to the atmosphere when the forest is cleared and/or burned. Biomass is also a useful variable for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions.

Not all biomass for domestic use originates from forests; significant quantities are obtained from non-forest lands such as woodlots, windbreaks and other line formations, home gardens, etc. It is recognised that this source should be assessed in the future, but it was beyond the present scope of the FRA 1990 Project.

2.1 Assessment by geographic region

To estimate the biomass density of forests use is made of existing volume over bark estimates (VOB) in the FORIS database which is converted to biomass density with the help of biomass estimation function and further "expanding" this value to take into account the biomass of the other above ground components.

Function for estimating biomass from volume information

BD (t/ha) = VOB * average WD * BEF

where: BD = biomass density
VOB = volume over bark of all trees to 10 cm minimum diameter (m3/ha)
WD = average wood density (t/m3); values obtained from FRA 1990 guidelines
BEF = biomass expansion factor

Research results based on actual inventory data across the tropics show that for tropical broadleaved forests biomass expansion factors are significantly related to stemwood biomass (SB) according to the following model:

$$\begin{aligned} BEF &= \exp\{3.213 - 0.506*\ln(SB)\} && \text{for } SB < 190 \text{ t/ha} \\ &= 1.74 && \text{for } SB \geq 190 \text{ t/ha} \end{aligned}$$

No model for calculating biomass expansion factors for coniferous forests is available at present because of general lack of data for this type of analysis. Therefore the estimates presented in the project guidelines were used.

This approach is of unknown reliability because much of the VOB data were estimated generally through extrapolation from existing local and international forest inventories. However, this method has the advantage of being pan-tropic and can therefore be used with area estimates for 1990 to produce an assessment of the total biomass of tropical forests.

2.2 Assessment by ecological region

The approach of estimating biomass density and biomass degradation, so far implemented for tropical Asia only, is based on a modelling method with GIS technology using various existing databases such as reliable inventory, population density and climatic data to produce digital maps of climatic indices and existing digital maps of vegetation, ecofloristic zones, soils and topography. The work is a cooperative effort between the Project and the staff of the University of Illinois, USA. The advantage of this method is that it produces biomass estimates directly without having to resort to an empirical extrapolation process. The disadvantage is that very few inventories give complete stand tables including small diameter classes for all species, thus not all countries in the tropics are covered by these estimates.

In the present approach, the following data layers (GIS-digital maps) are used as inputs to the modelling:

- Existing reliable forest inventory (with maps) data suitable for converting to actual biomass density (inventory coverage is very good for tropical America and Asia - but less for Africa);
- Existing spatial databases of the project including: ecofloristic zone maps (EFZ), Vegetation maps and subnational population data;
- Other spatial information including climatic index map (WCI) based on FAO meteorological station data, precipitation map, FAO soils map, topography map.

Potential biomass density (PB) is assumed to be a function of bio-climatic factors according to the following simple model:

PB (t/ha)= f[WCI, precipitation, soil (texture, depth, slope), topography]

Each of these factors is spatially represented by a numerical scale whose values were ranked according to how the particular factor affected biomass. The digital maps are overlaid according to the above model, and the results validated and calibrated using existing forest inventories for mature forests and other literature sources and the EFZ map.

GIS modelling provides results on biomass density (t/ha) by ecofloristic zone. These data could be combined with the area estimates to obtain total biomass by ecological and geographic region. Using the Project's vegetation map as a indication of forest cover for 1980, a spatial representation of forest biomass density was prepared by region.

3. SURVEY OF DEFORESTATION AND FOREST DEGRADATION USING HIGH RESOLUTION SATELLITE DATA

The estimates of forest cover area and deforestation rate at country level based on Phase 1 indicate the magnitude of deforestation.

To undertake control measures or simply to diagnose the problem, a better understanding of the change process is essential. For this purpose, the following types of questions need to be answered:

How do the tropical forest resources change?
How much is degraded? Fragmented?
What happens to deforested land?
Under which ecological and socio-economic conditions?
What are the causes of deforestation?

The only satisfactory way to provide reliable information on the process of change is to establish a forest resources monitoring system, using a globally compatible and consistent methodology. This provides reliable and location specific change information. In consideration of costs, precision and timeliness of results, a remote sensing based sampling approach was designed and used to cover the entire tropical zone in a time frame of about one year (see Figure 4). The specific objectives were:

(i) to achieve the highest level of consistency and precision in the assessment of forest cover state and change at global and regional levels;

(ii) to develop and disseminate a simple and robust monitoring technique for producing estimates of forest cover state and change at global and regional levels with application also at national level;

(iii) to provide spatial and statistical data for estimating class to class changes of land cover and forest cover categories between the two dates of interpretation at the sample locations and for producing change matrices at regional and global levels.

A distinctive feature of the methodology lies in the fact that it provides not only forest cover change data, but also change maps and matrices for each sample location. This enables estimation of class to class changes of land cover and forest categories between the two dates of interpretation at sample, regional and global levels: essential information for understanding the complex processes taking place, such as deforestation, fragmentation, degradation, afforestation, etc. An example of raster maps derived from image interpretation change maps and resulting transition matrix is given in Figure 5.

The Sample Survey Design

The survey is based on a sampling design covering all tropical countries. The World Reference System 2 (WRS2) for the LANDSAT satellites is used as the sampling frame. LANDSAT scenes covering approximately 3.4 million ha serve as the sampling unit.

A two stage stratified random sample is carried out. In the first stage the survey area is divided into sub-regions on a geographic basis. In the second stage the sub-regions are divided into forest cover strata. The allocation of samples to the sub-regions it made proportional to estimated deforestation. Within a sub-region sampling units are selected with equal probability.

Figure 4
Pan-tropical continuous forest resources survey design

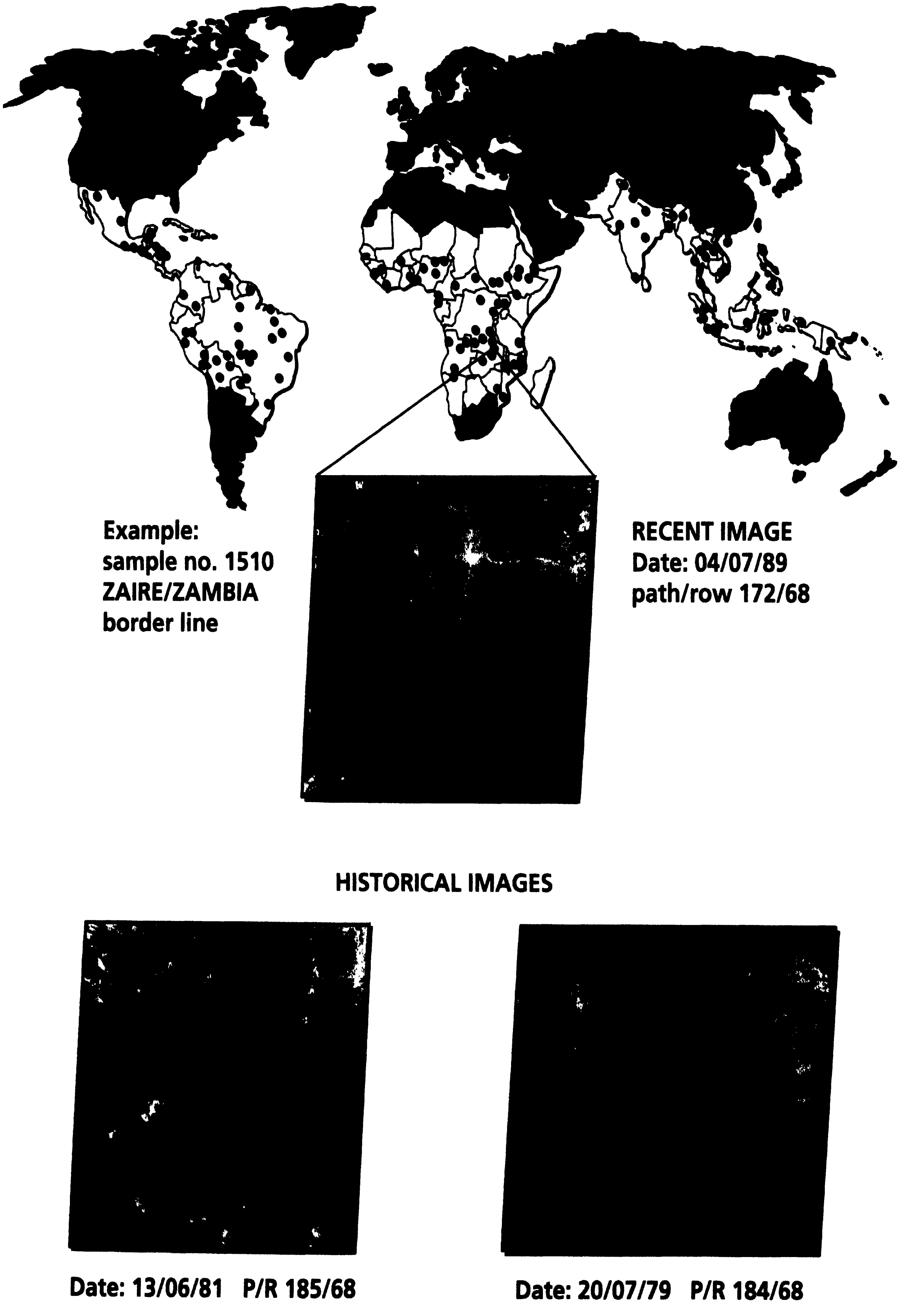
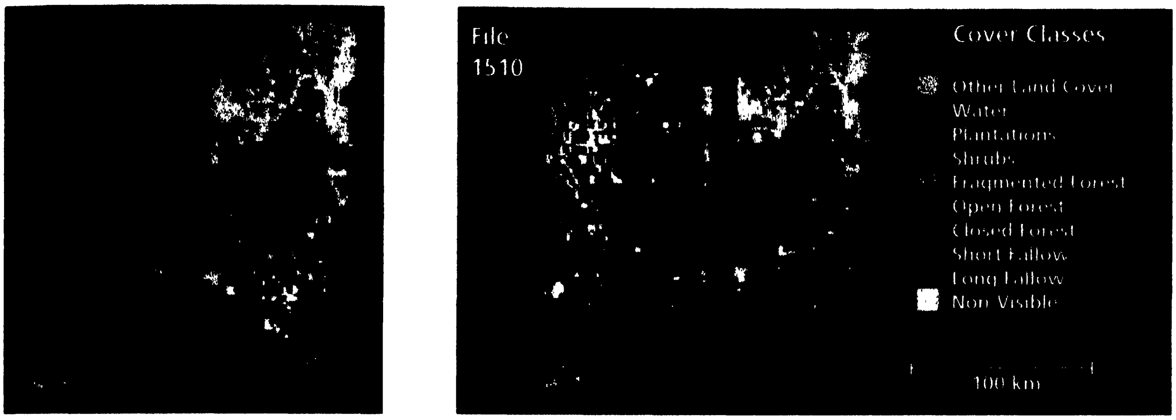


Figure 5
Example of spatial and statistical outputs - sample no. 1510, located along Zaire/Zambia border line

a: Maps derived from interpretation of satellite images of sample no. 1510



RECENT IMAGE — 04/07/1989

HISTORICAL IMAGES (common areas) — 13/06/81 20/07/79

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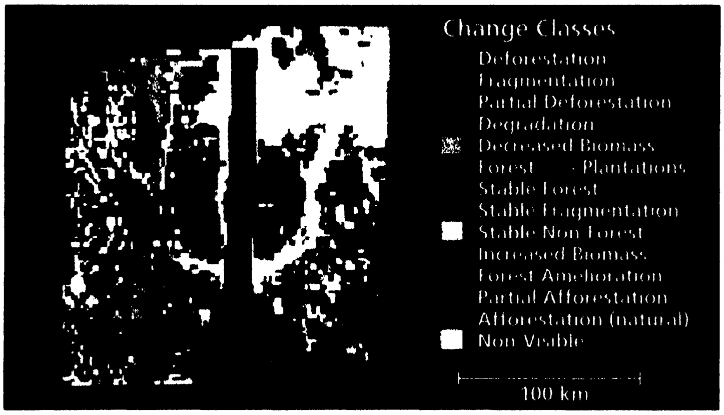
b: Change maps produced by comparison of common areas of recent and historical images. The 100 possible class combinations (10x10) have been reduced to 14 change classes for display purposes.



changes (1981-89) changes (1979-89)

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c: Sample no. 1510
– Standardized transition matrix computed for the reference period 1980– 1990

The two matrices reporting the cover class changes for periods 1981–1989 and 1980–1989 have been mathematically adjusted to the standard period 1980–1990 on the basis of transition probabilities and subsequently combined to form the comprehensive change matrix presented here.

		Cover Classes at year 1990									
Cover Classes at year 1980		Closed Forest	Open Forest	Long Fallow	Fragm. Forest	Short Fallow	Shrub	Other Land Cover	Water	Manmade Woody Veg.	Total at year 1980 '000 ha	Total at year 1980 %
Closed forest		1672.3	143.3			273.4		17.5			2106.5	71.2
Open forest		0.9	84.9			4.2		0.0			90.0	3.0
Long fallow												
Fragm. forest												
Short fallow						574.9		1.3			576.1	19.5
Shrubs												
Other land cover								160.6			160.6	5.4
Water									21.2		21.2	0.7
Manmade W.veg										2.4	2.4	0.1
Total at year 1990	'000 Ha	1673.2	228.2			852.4		179.4	21.2	2.4	2956.8	
	%	56.6	7.7			28.8		6.1	0.7	0.1		100.0

The main characteristics of the survey design are as follows.

- It covers the entire range of woody vegetation formations in the tropics including Closed forests, Open forests (including woodlands and wooded and tree savanna);
- It provides estimates of mean forest cover area and area change together with estimate of associated error.;
- It is **cost-effective** through use of two-stage stratification based on existing FORIS/ GIS information;
- It is based on the concept of **Continuous forest inventory** concept with a view to furnish consistent estimates of mean over time.

Table 2 gives the total number of sampling units by region, the number of sampling units selected for the study, and the expected sampling error at 95 percent probability level for forest area figures, which have been calculated using appropriate formulae for stratified random sampling.

Table 2
Allocation of sampling units by region and expected standard error

Continent	Sampling units		Proportion of forest/land area	Estimated forest area standard error (%)
	Total No.	Samp. size		
Africa	471	47	0.57	8.0
Asia & Pacific	277	30	0.45	8.2
Latin America & Caribbean	480	40	0.68	4.7
Total	**1228**	**117**	**0.59**	**3.9**

At each sample location, satellite images of the best quality and appropriate season, separated by an approximate ten year interval, are selected for observation. The image close to 1990 enables state assessment; whereas the area in common between the "1990" and "1980" images enables the change assessment.

The salient features from a remote sensing point of view are the following:

(i) **Interdependent interpretation procedure**; this interpretation approach secures the highest level of spatial consistency between historical and recent image classification.

(ii) **Standard classification** of various forest classes (closed, open, with shifting cultivation, fragmented) on a pan-tropical basis.

(iii) **Change matrix**; each sample produces a transition matrix from which the processes of change can be analysed.

(iv) **Image archive**; all images used represent permanent reference as part of a continuous time series; in future these images will be used to estimate the speed of change (3 or more time series)

Inter-dependent Interpretation Procedure

1. Image characteristics
   - LANDSAT MSS (20 percent of recent images will be TM) and IRS (Indian Remote Sensing Satellite) satellite data
   - Two dates, one close to 1990, one close to 1980, at least five years apart, same season (preferably beginning of dry season)
   - Standard enhancement for vegetation assessment
   - Common cloud-free overlay of one million ha minimum

2. Interpretation procedure
   - Interdependent interpretation, namely visual interpretation of both images by the same interpreter (coming from the region and familiar with the location) at the same time
   - Standard and globally compatible land use classification

3. Image interpretation recording
   - User-friendly data recording from dot grid using customized LOTUS 1-2-3® spreadsheet software
   - Generation of change matrices showing land use changes

4. Field verification of selected samples in cooperation with national forest services and remote sensing agencies

The interpretation was implemented at selected regional and national forestry and/or remote sensing institutions which have a good knowledge of the sample locations and traditionally involved in forest resources assessment activities. With the two-fold objective of strengthening national capacities for forest monitoring and improving the quality of image interpretation, the Project has so far organised three regional workshops and eight training sessions with national institutions, benefitting 27 countries and 81 participants.

The results and quality of the interpretation done by local institutions are centrally reviewed and evaluated. A database is established and analyses carried out as will be presented later. The results of the remote sensing survey have found the following applications.

- In combination with demographic and ecological parameters, the sampling units so far completed in tropical Africa have been used to develop a regional deforestation model which has helped to define forest area at year 1990 and deforestation rates for the region.

- In order to produce the first dynamic description of changes in land use and forest categories in tropical Africa for the period 1980 to 1990, the results of the 31 available sampling units have been analysed as a whole and by ecological characteristics.

- A very preliminary but interesting comparative analysis of the processes of change in forest area among the three regions for the period 1980-1990 have been done using all available sample units.

Considering the extremely poor information available on the tropical forests in general, and on the on-going processes of change of the tropical forest resources in particular, this project component could be considered an important achievement.

4. ASSESSMENT OF FOREST FRAGMENTATION USING COARSE RESOLUTION SATELLITE DATA

A continuous forest cover is termed fragmented when in the course of time it is broken down into disjunct parts by conversion of parts of the cover to non-forest uses, e.g. by building of roads or introduction of agricultural crops, etc.

Different indices have been developed in the past years to quantify the landscape variability including specifically forest fragmentation. In the framework of the Project, two of the indices were used: the Perimeter Area Index (PAI) and the edge/core ratio (ECR).

Fragmentation indicators

The *Perimeter Area .Index* (PAI) for forests located in a geographic region is computed by the following formula:

$$PAI = 0.282095 * \frac{P_a}{\sqrt{A*N}}$$

Where N is the number of forest islands, P_a their total measured perimeter and A the total area.

The *edge/core ratio (ECR)* in a forest zone is derived from the following formula:

$$ECR = \frac{edgeforest(\%)}{edgeforest(\%) + coreforest(\%)}$$

Where "edge forest" is the forest area on the edge zone, 10 km wide here, from the edge of the mapped forest to its interior. This is usually the area most subject to anthropic impact.

"Core forest", is the inner forest areas, in the present case assumed to be 10 km beyond the edge of forest. This is usually the undisturbed forest area.

The main objective of the study on fragmentation was to investigate the relationship between fragmentation and variables such as deforestation and forest degradation.

Vegetation maps derived from NOAA-AVHRR satellite data (1 km resolution) were used as the source document due to their resolution and recent acquisition date. Two areas were chosen for the study, namely the West Africa and the Amazon Basin subregions, because they represent two interesting and contrasting patterns of forest fragmentation.

Chapter IV

ASSESSMENT RESULTS

1. FOREST COVER STATE AND CHANGE ASSESSMENT

1.1 Main results by geographic region

The results presented in this section are based on a time-series analysis of reliable forest cover observations of 644 subnational units contained in FORIS. Some of the observations are single date and others multi-date spread over the period 1960 to 1990 as shown in Table 3.

Table 3
Observations used for state and change assessment

Frequency of observations	Number of observed subnational units			
	1961-1970	1971-1980	1981-1990	Total
Single date	18	330	151	499
Multi-date	53	54	38	145
Total	**71**	**384**	**189**	**644**

The FORIS database is an important output of the assessment process and marks the starting point of tropical forest resources assessment on a continuing basis. Using the database, it is possible to make a study of historic trends and future prospects. As more multi-date observations become available and are added to the database, the precision of estimates, particularly of change rates, is expected to increase.

The current situation. As described in the chapter on Methodology, the estimations of forest cover and changes have been done at subnational level. Results are then aggregated at national level for reporting purposes (see Annex 1). The national estimates are further aggregated at subregional, regional and global tropical levels as presented in Table 4.

The **pan-tropical forest cover** was 1,756 million ha at end 1990 and 1,910 million ha at end 1980. Thus, average annual deforestation during the past decade amounts to 15.4 million ha (0.8 percent in compound annual rate of deforestation). The largest extent of forest cover was in Latin America and the Caribbean (918 million ha: 52 percent of the total tropical forest area), followed by Africa (528 million ha: 30 percent), and Asia and Pacific (311 million ha: 18 percent). The annual loss of forest cover by region was: Latin America and the Caribbean 7.4 million ha (0.8 percent), Asia and Pacific 3.9 million ha (1.2 percent) and Africa 4.1 million ha (0.7 percent).

Among the subregions, the following have relatively high rates of deforestation: West, East Sahelian and Southern Africa; Continental and Insular Asia; Central America and Mexico.

Table 4
Estimates of forest cover area and rate of deforestation by geographical subregion

Geographic subregion / region	Number of countries	Land area	Forest cover		Annual deforestation 1981-90	
		million ha	1980 million ha	1990 million ha	million ha	% per annum
Africa	**40**	**2,236.1**	**568.6**	**527.6**	**4.1**	**0.7**
West Sahelian Africa	6	528.0	43.7	40.8	0.3	0.7
East Sahelian Africa	9	489.7	71.4	65.5	0.6	0.9
West Africa	8	203.8	61.5	55.6	0.6	1.0
Central Africa	6	398.3	215.5	204.1	1.1	0.5
Trop. Southern Africa	10	558.1	159.3	145.9	1.3	0.9
Insular Africa	1	58.2	17.1	15.8	0.1	0.8
Asia & Pacific	**17**	**892.1**	**349.6**	**310.6**	**3.9**	**1.2**
South Asia	6	412.2	69.4	63.9	0.6	0.8
Continental S.E. Asia	5	190.2	88.4	75.2	1.3	1.6
Insular S.E. Asia	5	244.4	154.7	135.4	1.9	1.3
Pacific	1	45.3	37.1	36.0	0.1	0.3
Latin America & Caribbean	**33**	**1,650.1**	**992.2**	**918.1**	**7.4**	**0.8**
C. America & Mexico	7	239.6	79.2	68.1	1.1	1.5
Caribbean	19	69.0	48.3	47.1	0.1	0.3
Trop. South America	7	1,341.6	864.6	802.9	6.2	0.7
Total	**90**	**4,778.3**	**1,910.4**	**1,756.3**	**15.4**	**0.8**

Source: FORIS database

Comparison with FAO/UNEP 1980 Assessment. The results of the present assessment can be compared to those from the previous FAO/UNEP 1980 Forest Resources Assessment. For 76 countries assessed in common and covering approximately 98 percent of the tropical land area, the estimates are as presented in Table 5.

Table 5
Comparison of FAO/UNEP 1980 assessment with FAO 1990 assessment

Estimate	1980 FAO/UNEP assessment (million ha)	1990 FAO assessment (million ha)
Forest area by end 1980	1,935	1,910
Annual rate of deforestation		
- during 1981-85	11.3	--
- during 1981-90	--	15.4

Differences in the estimates of the 1980 forest cover and in annual deforestation rates for partly overlapping periods of the 1980s between both assessments at global (as well as regional and subregional) levels arise mainly from two factors: the increased amount of recent information from surveys related to 1980 and following years in the 1990 assessment; and the improved procedures for updating estimates at different years adopted by the latter. Therefore the differences in annual deforestation rates do not necessarily reflect an acceleration of the deforestation process during the 1980s.

1.2 The state of forest ecosystems

The report on the state of forest ecosystems, as presented in this section, is an important element of biodiversity assessment. Combined with data on species richness, the estimate of area losses by ecosystem can be used to make indicative estimates of loss of species richness.

Biodiversity assessment

According to the international convention, biodiversity here means· "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

The present assessment limits itself to a subset of ecosystems, namely tropical forests, and within that to mainly tree species, although the approach of the assessment is general and could be easily extended to include other plant and animal species.

For the present reporting, the ecofloristic zones were grouped into four broad forest formations: one upland and three lowland. Figure 6 provides an overview of their distribution. The state of the tropical forests by formation and by country is given in Annex 1 and a summary in Table 6.

At end 1990 lowland formations were 1,544 million ha (88 percent of the total tropical forest area) and upland (hill and montane) formations 204 million ha (12 percent). Among the lowland formations, the tropical rainforests constituted the largest portion, namely 718 million ha (or 41 percent), the moist deciduous forests 587 million ha (33 percent) and the dry and very dry zone forests 238 million ha (14 percent). The rest of the forests, nearly 8 million ha, were scattered in the non-forest zone.

The annual losses of forest cover by ecological zone were: the tropical rainforests 4.6 million ha (0.6 percent), the moist deciduous forests 6.1 million ha (1.0 percent), the dry and very dry zone forests 2.2 million ha (0.9 percent) and the upland formations 2.5 million ha (1.1 percent).

Figure 6
Forest zones in the tropics

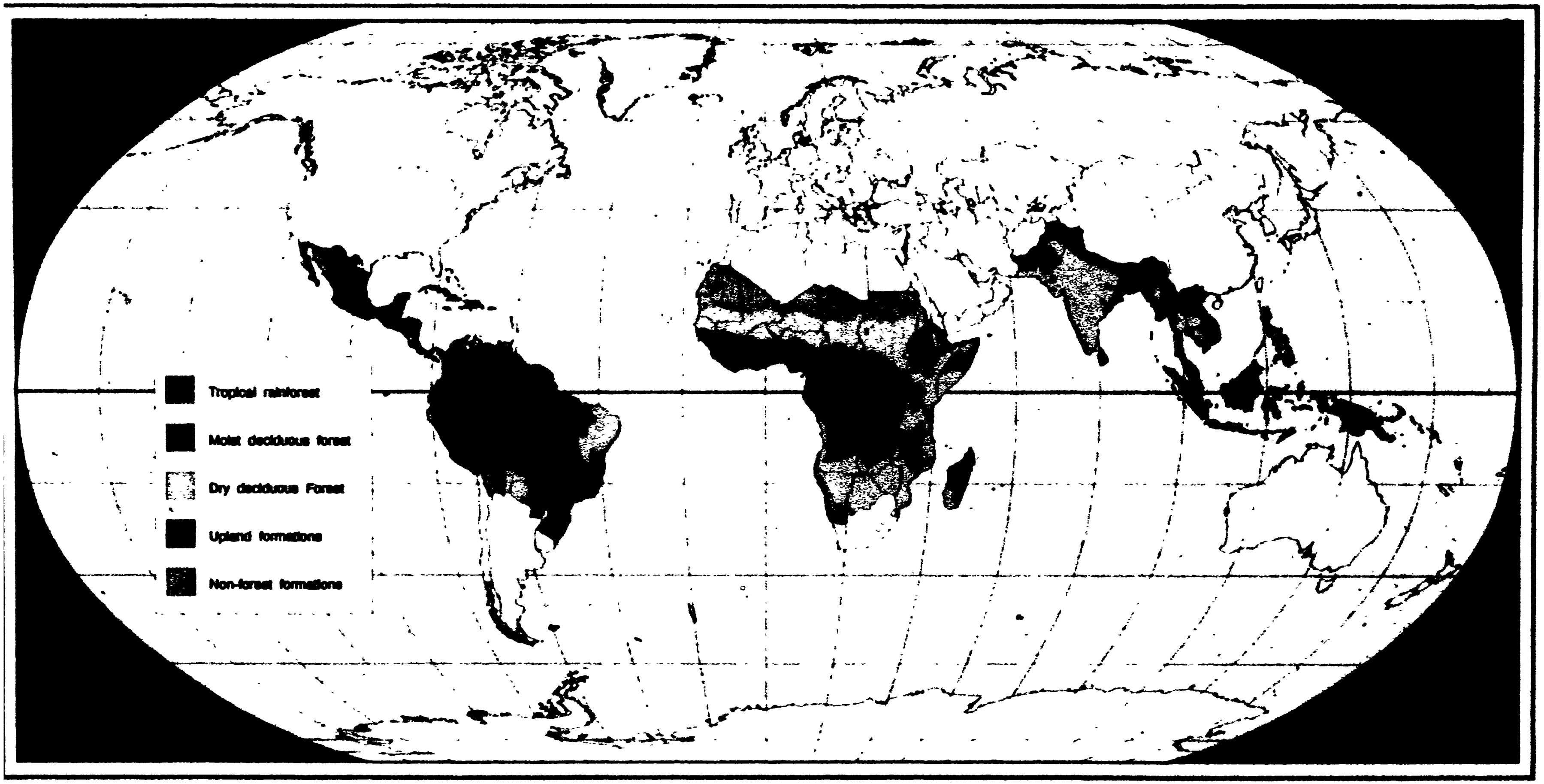


Table 6
Estimates of forest cover area and rate of deforestation by main ecological zone

Ecological zone	Land area	Population density 1990	Annual pop. growth 1981-90[1]	Forest cover 1990		Annual deforestation 1981-90[1]	
	million ha	inh / km²	% per annum	million ha	% land area	million ha	% per annum
FOREST ZONE	**4,189.7**	**57**	**2.4**	**1,748.2**	**42**	**15.3**	**0.8**
Lowland formations	**3,476.6**	**57**	**2.3**	**1,543.9**	**44**	**12.8**	**0.8**
Rainforest	937.1	41	2.2	718.3	76	4.6	0.6
Moist deciduous	1,298.6	55	2.4	587.3	46	6.1	1.0
Dry and very dry	1,241.0	70	2.3	238.3	19	2.2	0.9
Upland formations (hill and mountain forest)	**713.1**	**56**	**2.6**	**204.3**	**29**	**2.5**	**1.1**
NON-FOREST ZONE (Alpine areas, deserts)	**588.6**	**15**	**3.1**	**8.1**	**1**	**0.1**	**1.0**
TOTAL TROPICS [2]	**4,778.3**	**52**	**2.4**	**1,756.3**	**37**	**15.4**	**0.8**

Notes:
[1] Compound interest formulae were used for population growth and deforestation rate calculations.
[2] Totals may not tally due to rounding.

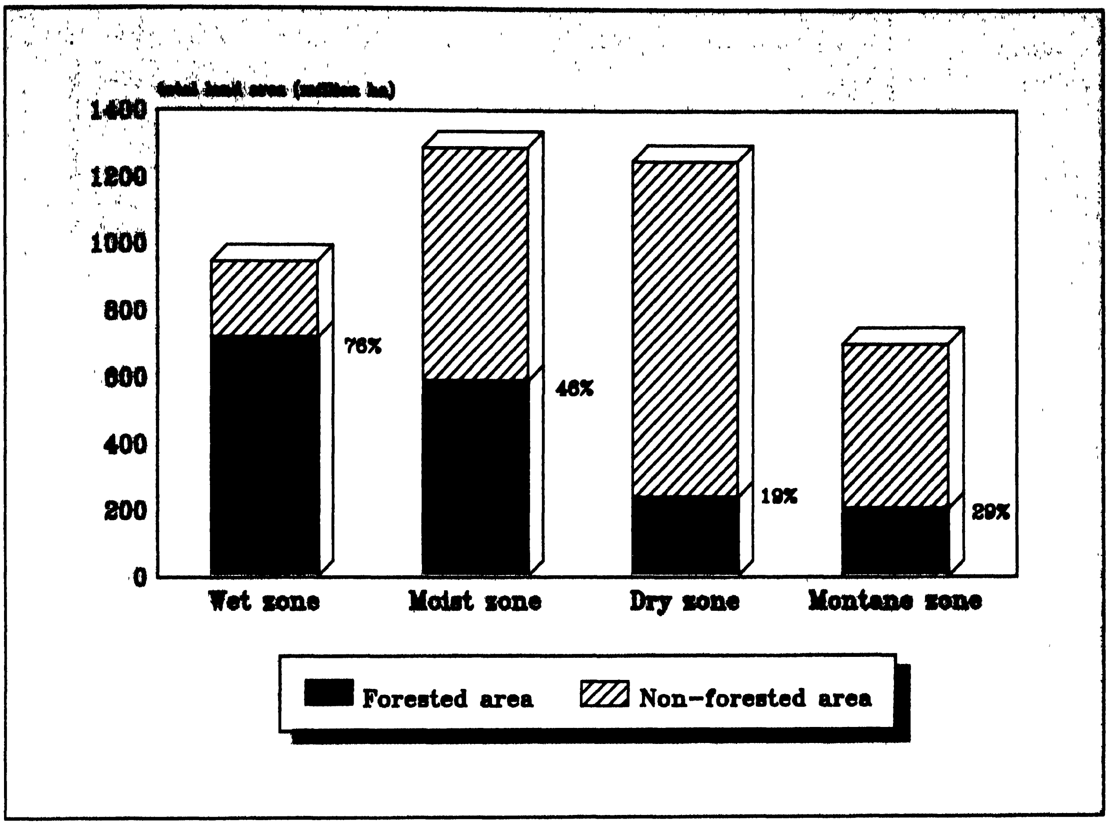
Source: FORIS database

Comparing the forest area to land area ratio (see Figure 7) for each ecological zone, it appears that 76 percent of the tropical rainforest zone is still covered with forest. As expected, the percentage of forest cover declines with drier conditions and differences are quite obvious: 46 percent are forested in the moist deciduous zone, 30 percent in the dry deciduous zone and 19 percent for the dry and very dry zones together. One can assume that in the very dry zone the original forest area was considerably less than 100 percent of the total land area. This is in contrast to the rainforest and moist zones where the original forest area was close to 100 percent.

Assessment of biodiversity loss. The estimates of deforestation by ecofloristic zone, grouped by ecological region for reporting purposes, provide a basis for estimating biodiversity loss at ecosystem level. This information can be transformed into likely loss of species richness in the following manner.

The estimates of forest cover loss by main ecological region given in Table 6 are combined with information about human pressure by region. This is graphically presented in Figure 8.

Figure 7
Present forest cover by ecological zone



Data on distribution of higher plants (i.e. vascular plants) available for almost all tropical countries, are plotted against potential forest area of the respective country (see Figure 9). Different trends can be identified in the species area relationships according to the dominant ecological region in the countries. The gradients shown therein are representative of the forest formation sensitivity in terms of species loss due to deforestation. The same ecological conditions characterise also the forest formations for which the Project assessed the deforestation (see Figure 8). This fact is highlighted in Table 7 where annual rate of species loss was computed as due to deforestation.

The information provided permits a semi-quantitative evaluation of the risk of species loss due to forest area loss. It is important to highlight that the forest area loss, which is different in different forest formations and regions, has also different impact on the impoverishment of species richness.

The tropical rainforests of Asia seem to be most endangered in terms of likely impact of deforestation on species richness. The estimated loss is twice, though the area deforested is about half, that of Latin America and the Caribbean.

Figure 8
Forest proportion vs. population density by forest formation

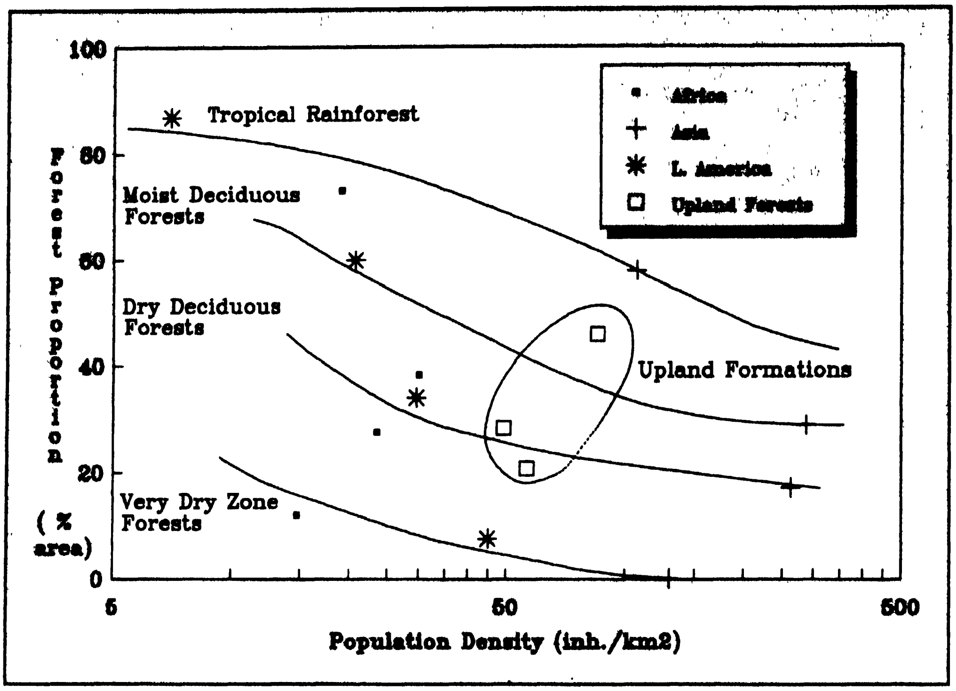


Figure 9
Species/area relationships, plant species - 86 countries

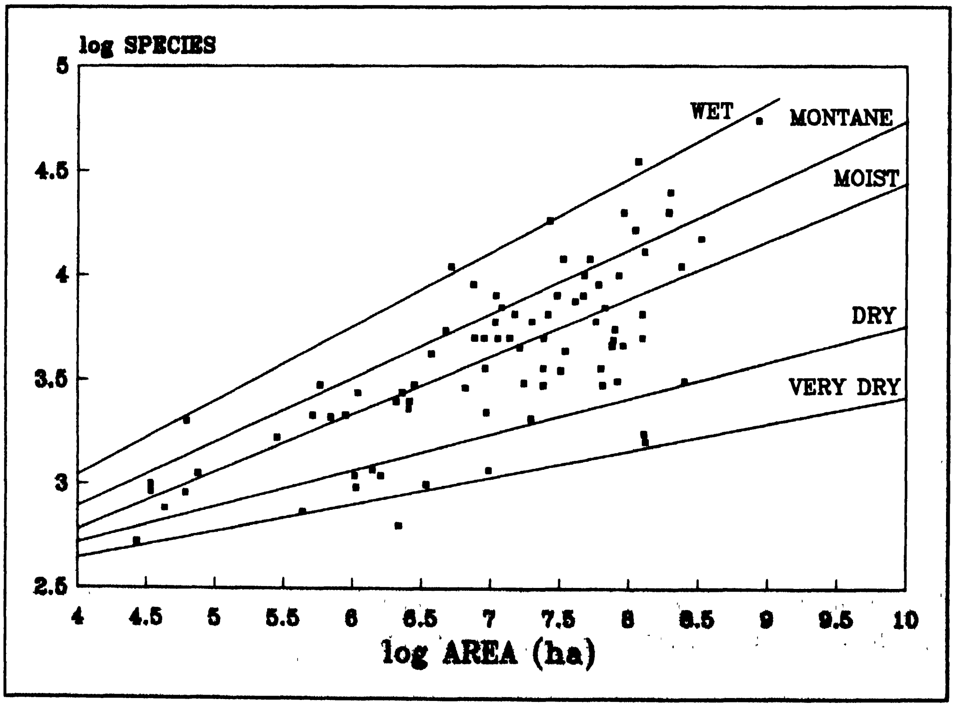


Table 7

Indicative estimates of species loss amongst higher plants due to deforestation

Ecological zone	Forest cover area		Deforestation rate	Relative species richness	Indicative species loss
	1980	1990	1981-90	1990	1981-90
	million ha	million ha	million ha	Species number	% Loss
Africa					
Tropical rainforest	91	87	4.7	30,700	2.0
Moist deciduous forest	274	251	22.5	13,000	2.5
Dry and very dry zone	162	151	10.8	1,900	1.0
Upland formations	38	35	2.9	12,300	2.5
Asia & Pacific					
Tropical rainforest	199	177	21.6	40,400	4.3
Moist deciduous forest	48	42	6.6	7,600	4.3
Dry and very dry zone	46	41	4.7	1,600	1.6
Upland formations	53	47	5.8	13,500	3.8
L. America & Caribbean					
Tropical rainforest	474	454	19.4	57,900	1.6
Moist deciduous forest	326	294	31.8	13,700	3.0
Dry and very dry zone	52	46	6.2	1,600	1.9
Upland formations	138	122	16.2	18,400	4.0

2. FOREST BIOMASS STATE AND CHANGE ASSESSMENT

2.1 Assessment by geographic region

The country level estimates are given in Annex 1 and a summary in Table 8. It is observed that the Caribbean, Central Africa and in Insular South East Asia subregions have still more than 200 tons per hectare, while the lowest values are found in tropical Southern Africa and in Sahelian Africa. It may also be noticed that the biomass per capita values are extremely low in South Asia due to very high population pressure. Low values are also found in West Africa, Sahelian Africa and Central America. It is remarkable that the average biomass per capita of Asia is only one fourth that of Africa and less than one tenth that of Latin America and the Caribbean.

Annual loss of biomass is estimated slightly over 2,500 million tons of which more than 50 percent is contributed by the Latin America region, nearly 30 percent by tropical Asia and about 20 percent by tropical Africa.

Table 8

State of forest biomass and annual losses due to deforestation

Region	Forest cover area	Forest biomass			Annual loss due to deforestation (1981-90)		
	1990	Average per ha	Total	Average per capita	Area	Biomass	
	million ha	tons / ha	10^6 tons	t/person	million ha	million tons	% of total
Africa	**527.6**	**133.0**	**70,144**	**145**	**4.1**	**479**	**19**
West Sahelian Africa	40.8	64.5	2,628	61	0.3	19	0
East Sahelian Africa	65.5	80.3	5,254	43	0.6	48	2
West Africa	55.6	97.3	5,409	34	0.6	58	2
Central Africa	204.1	227.1	46,349	878	1.1	259	10
Tropical Southern Africa	145.9	60.5	8,824	93	1.3	81	3
Insular Africa	15.8	106.5	1,680	140	0.1	14	0
Asia & Pacific	**310.6**	**180.8**	**56,170**	**36**	**3.9**	**732**	**29**
South Asia	63.9	99.6	6,368	6	0.6	55	2
Continental South East	75.2	187.1	14,075	80	1.3	246	10
Insular South East	135.4	212.9	28,837	109	1.9	410	16
Pacific	36.0	191.4	6,890	1,718	0.1	22	1
Latin America & Caribbean	**918.1**	**185.0**	**169,844**	**426**	**7.4**	**1,303**	**52**
Central America & Mexico							
Caribbean	68.1	95.2	6,483	55	1.1	106	4
Tropical South America	47.1	247.0	11,638	337	0.1	30	1
	802.9	189.0	151,723	615	6.2	1,167	46
Total	**1,756.3**	**168.6**	**296,158**	**121**	**15.4**	**2,514**	**100**

Source: FORIS database

2.2 Assessment by ecological region

Estimates of potential and actual biomass density, as determined by modelling in GIS for most of tropical Asia are shown in Table 9. It is clear that the forests of insular Asia have both higher potential and actual biomass densities than those of continental Asia. The general trends in biomass density by ecoregion are consistent with expected patterns of biomass distribution: decreasing biomass density with decreasing moisture and increasing elevation. Forests in the continental dry zone and the insular seasonal zone appear to be the most degraded with actual biomass densities that are about 30 to 40 percent of their potential.

Table 9

Potential (1980s forest area, without human impact) and actual (with human impact) biomass density (t/ha) for forests of tropical Asia by ecological zone.

Ecoregion	Potential (t/ha)	Actual (t/ha)	Ratio of actual to potential
Continental:			
Lowland moist	449	225	0.50
Lowland seasonal	350	187	0.53
Lowland dry	244	76	0.31
Montane moist	353	222	0.63
Montane seasonal	306	155	0.51
Insular:			
Lowland moist	543	273	0.50
Lowland seasonal	452	174	0.38
Montane moist	504	254	0.50

3. THE PROCESS OF DEFORESTATION AND FOREST DEGRADATION

The study on the process of deforestation and forest degradation was conducted using the multi-date remote sensing based sample survey described in the chapter on Methodology.

3.1 Assessment by geographic region

The results are first presented for the Africa region based on 31 of 47 samples representing the entire geographical and ecological conditions, followed by a brief explanation of findings for the other regions.

For each sample a change matrix has been produced from the interdependent interpretation of two satellite images; the historical image acquired around year 1980 and the recent one acquired around year 1990.

The compilation of change matrices. The observed change matrices have been mathematically transformed into standardised matrices for the exact period 1980 to 1990 and further aggregated to produce the total given in Table 10. The class to class changes reported in this table highlight the complexity of the dynamics involved. As is expected from the process of such a large area almost all possible class-to-class changes are represented. However, most of the area changes are located above the diagonal implying a loss of forest area or cover, fragmentation, etc.

Another important inference can be derived from this table: thinking only in terms of deforestation is too simplistic. Deforestation is only one of the types of change in a complex process of area changes. It is important to consider all the facts of the change.

Table 10
The change matrix for the Africa region based on the 31 samples

Classes at year 1980	Classes at year 1990 (areas in '000 ha)									Total 1980	
	Closed forest	Open forest	Long fallow	Frag-mented forest	Short fallow	Shrub	Other land cover	Water	Planta-tions	'000 ha	%
Closed forest	16,781	382.1	82.6	291.8	524.3	9.5	247.5			18,319.3	24.5
Open forest	23.6	10,049	48.3	371.2	117.8	12.7	397.3	0.1	1.4	11,021.8	14.8
Long fallow	7.7	14.6	556.8	1.6	51.7	4.4	28.5			665.4	0.9
Fragm. forest	24.1	40.0	1.0	8,088.8	5.8	7.7	293.5			8,461.1	11.3
Short fallow	7.6	10.9	9.6	2.1	2,254.8		53.3	0.4		2,338.6	3.1
Shrubs	0.8	10.8		1.1		3,877.9	154.3	0.1		4,055.1	5.4
Other land cover	16.9	38.2	11.0	63.1	34.3	86.6	26,452	51.2		26,752.8	35.8
Water	0.5			0.5	3.2	0.1	81.5	2,960.1		3,045.9	4.1
Plantations					0.4		0.4		4.6	5.3	0.0
Total 1990											
'000 ha	**16,863**	**10,546**	**709.2**	**8,820.2**	**2,992.4**	**3,999.0**	**27,718**	**3,011.9**	**6.0**	**74,665.2**	
%	**22.6**	**14.1**	**0.9**	**11.8**	**4.0**	**5.4**	**37.1**	**4.0**	**0.0**		**100.0**

Interpretation of the change matrix (Table 10) Comparing the row totals, showing the situation at year 1980, and the column totals, showing the situation at year 1990, illustrates the total area lost or gained by a class (see Figure 10).

Specific class-to-class changes can be read from each row. For example, the following changes from closed forest in 1980 can be read from the "closed forest" row. These are also illustrated in Figure 11.

During the period under consideration, 8.4 percent of the original closed forest cover (18,319,300 ha - 16,781,000 ha = 1,538,300 ha) was transferred to other classes.

(i) 247,500 ha (16.1 percent of the area changed) changed to other land cover;

(ii) 524,300 ha (34.1 percent) was converted to short fallow agriculture which indicates the spontaneous pressure of rural population, rather than planned land use change;

(iii) 291,800 ha (19.0 percent) changed to fragmented forest. Fragmented forest results from partial deforestation, usually by progressive clearing of small patches of forest, which creates a mosaic of forest and non-forest. In turn the fragmented forest mainly changed to other land cover (permanent agriculture) which implies that fragmentation is an intermediate stage toward permanent agriculture.

Figure 10
Land cover changes, Africa: 1981-90

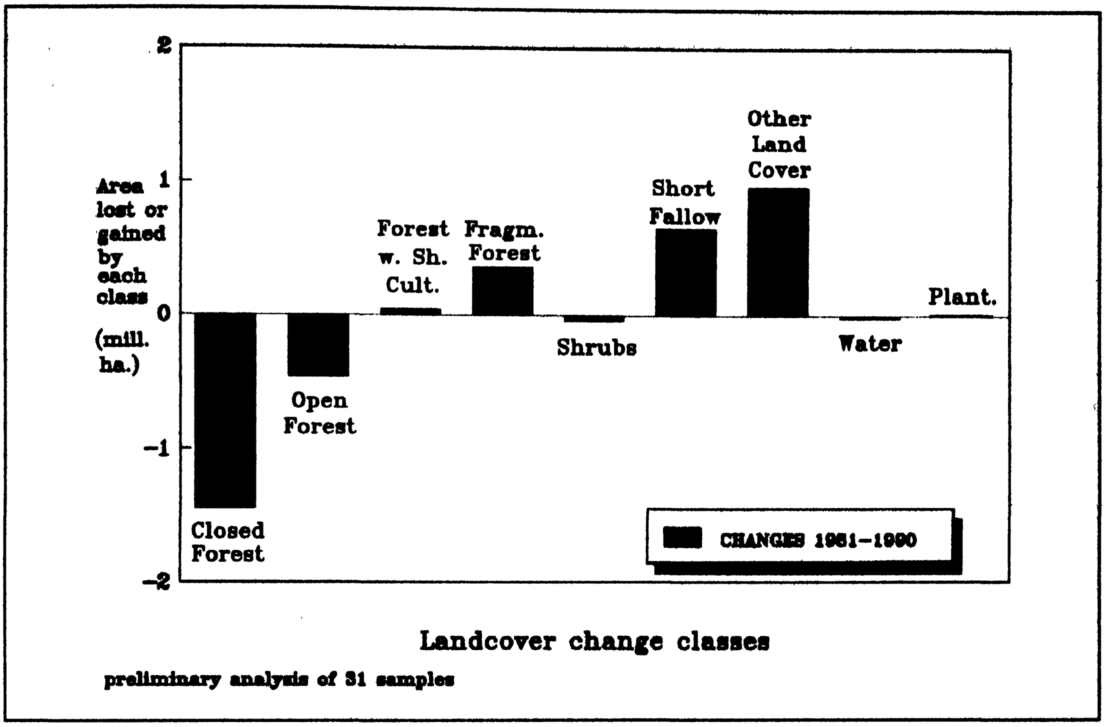
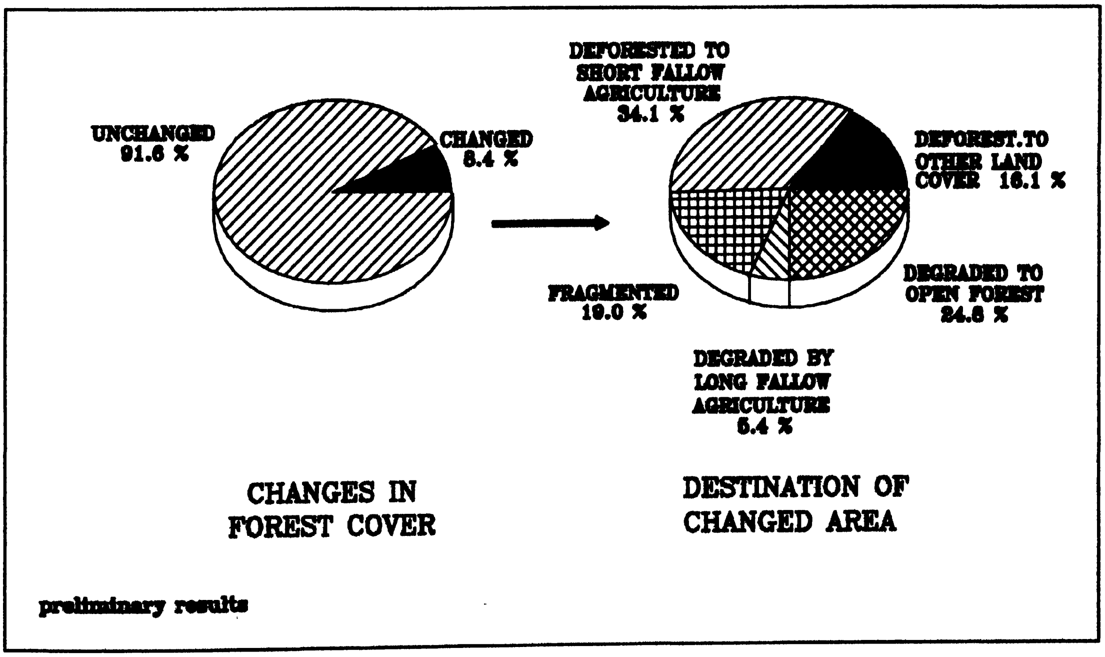


Figure 11
Changes in closed forest cover, Africa: 1981-90



(iv) 82,600 ha (5.4 percent of the area changed) changed to long fallow. This small portion of the total change indicates that this practice is relatively minor and of little relevance in this region;

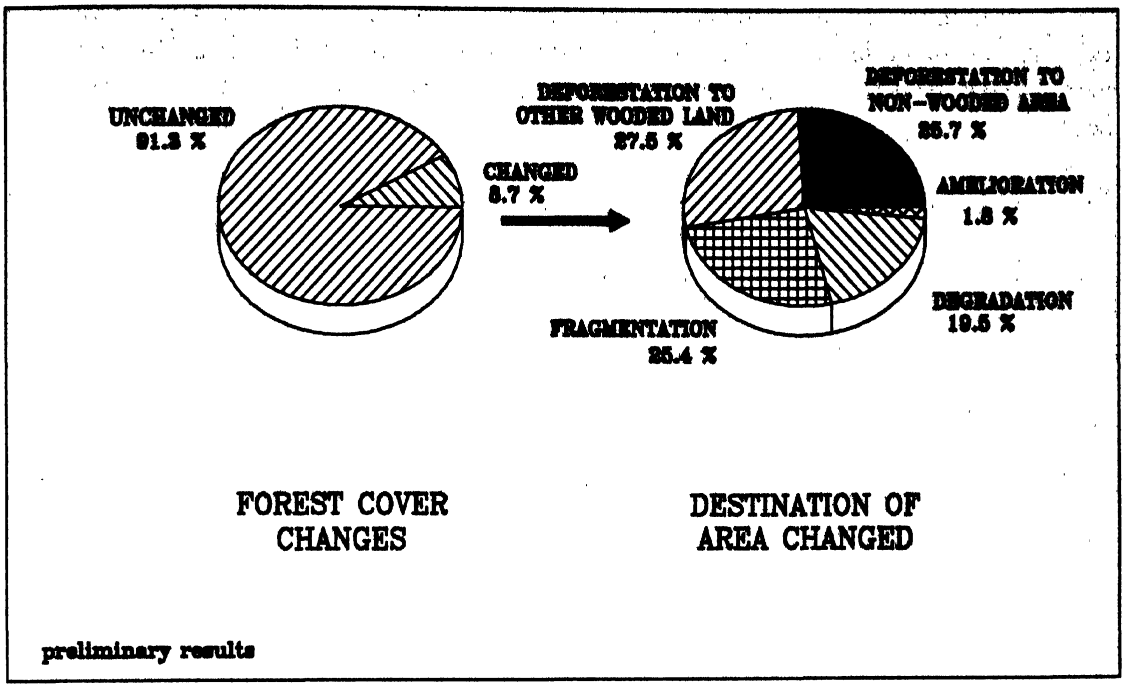
(v) 382,100 ha (24.8 percent) changed to open forest, which indicates degradation by loss of density of the forest canopy. This is probably the effect of grazing and related fire practices, selective logging, fuelwood exploitation etc.

(vi) 9,500 ha (0.6 percent) changed to shrub vegetation, which as in the case of conversion to long fallow agriculture, indicates that this practice is of little relevance in this region.

The changes described above refer only to the area originally in the land-cover class of closed forest. In order to achieve a more comprehensive overview, classes have been aggregated for analysis from nine land cover classes into five groups as follows:

Land cover groups	***Land cover classes***
• Continuous (or non-fragmented) forest	Closed forest Open forest Long fallow
• Fragmented forest	Fragmented forest
• Other wooded land	Shrubs Short fallow
• Non-wooded area	Other land cover Water
• Plantations	Plantations (forest and agric. plant.)

Figure 12
Changes in continuous forest cover, Africa: 1981-90



The following points may be noted in the above grouping:

(i) The changes have been grouped together on an increasing scale of biomass loss. The changes within the continuous forest group due to reduction of density (closed to open forest) or conversion of forest to long fallow are termed here "forest degradation".

(ii) The changes from continuous forest cover to fragmented forest cover are termed "fragmentation" or "partial deforestation".

Two types of "deforestation" are identified:

(iii) "Deforestation to other wooded land" where the forest is lost but a certain woody biomass remains;

(iv) "Deforestation to non-wooded area" where the forest is lost and no woody biomass remains.

The positive changes within the continuous forest are termed "amelioration". This represents an increase in density within the forest (open forest to closed forest and long fallow to forest).

In 1980 the area of (continuous) forest cover was some 30 million ha in the sampled area of Africa. Figure 12 describes what has happened to the 2.6 million ha (8.7 percent) of continuous forest cover changed during the period 1980-1990.

With the exception of the negligible positive changes represented by Amelioration (1.8 percent, increase of density or decrease of perturbation in Continuous Forest) and by conversion to Plantation (0.05 percent), the bulk of the area has undergone negative changes as described below:

(i) 19.6% **Degradation** (decrease of canopy density or increase of perturbation)

(ii) 25.4% **Fragmentation** (partial deforestation) On average this process represents a loss of two thirds of the original forest area, replaced by progressively increasing agricultural practices.

(iii) 27.5% **Deforestation:** (forest to other wooded land cover group) This indicated two types of processes: loss of forest by change of its physiognomic characteristics (from forest to shrubs) and establishment of the traditional short fallow agriculture. The former process is rare while the latter is much more important in Africa. In both cases a certain amount of woody biomass remains.

(iv) 25.7% **Deforestation:** (forest to non-wooded area) This represents total loss of woody biomass. It identifies the extreme level of degradation (denuded land), conversion to permanent agriculture or creation of water bodies (the latter being here negligible).

The sample survey data have been further analysed by ecological zone and corresponding change matrices produced.

3.2 Assessment by ecological region

In order to understand these processes in an ecological context, the results obtained from the remote sensing based sample survey were aggregated by ecological zone. Observations available so far justified main groups: (i) **lowland wet and moist forest zone** (with short or long dry period); (ii) **Lowland dry forest zone** (from dry to very dry); and (iii) **Montane moist forest zone** (moist montane and pre-montane with short or long dry period).

Results are first presented and discussed for the Africa region, followed by Asia and Latin America. Table 11 gives information about the sampled area in Africa, by ecological zone. The results indicate that the percentage of forest changes in the moist lowland zones (11 percent) is much greater than those of the dry lowland and moist montane zones (5.8 percent and 4.7 percent respectively). This can be explained by the higher suitability of the moist lowland zone to agricultural practices (and probably by the higher population density) in comparison with the other zones.

Table 11 and Figure 13 show, in tabular and graphical form, the types and extent of changes undergone during the period 1980-1990, by forest formation.

Table 11

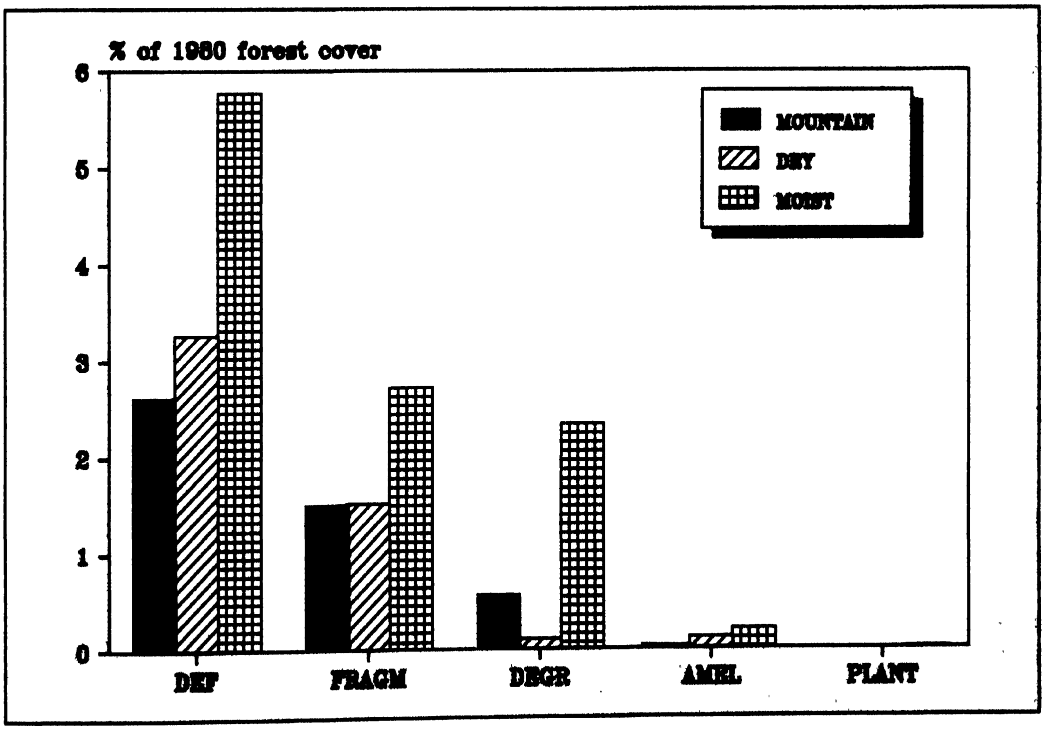
Changes in forest area[1/] by ecological zones - Tropical Africa region

Parameters	Moist lowland		Dry lowland		Moist montane		Total	
	'000 ha	%	'000 ha	%	'000 ha	%	'000 ha	%
Sampled area characteristics								
Land area studied	30,175.0		27,693.3		13,751.0		71,619.3	
Forest area 1980	17,503.6		8,697.0		3,805.8		30,006.4	
% of land area		58.0		31.4		27.7		41.9
Forest area changed 1980-90	1,931.0		508.0		179.8		2,618.8	
% of forest area 1980		11.0		5.8		4.7		8.7
Types of forest area changes (80-90)								
Deforested to non-wooded	380.9	19.7	193.3	38.0	99.2	55.2	673.4	25.7
Deforested to other wooded	629.6	32.6	90.4	17.8	0.6	0.3	720.5	27.5
Total deforested	1,010.5	52.3	283.6	55.8	99.8	55.5	1,393.9	53.2
Fragmented	475.7	24.6	131.4	25.9	57.4	31.9	664.6	25.4
Degraded	408.1	21.1	83.3	16.4	21.7	12.0	513.0	19.6
Ameliorated	35.3	1.8	9.7	1.9	1.0	0.6	45.9	1.8
Planted	1.4	0.1	0.0	0.0	0.0	0.0	1.4	0.1
Total area changed	**1,931.0**	**100.0**	**508.0**	**100.0**	**179.8**	**100.0**	**2,618.8**	**100.0**

[1/] Includes all forest classes except fragmented forest

Figure 13

Continuous forest cover change by main ecological zone, Africa: 1981-90



In all cases deforestation remains the major type of change. It is interesting to note, however, that while the larger share of the deforested area in the moist lowland zone goes to other wooded land, in the other two zones this type of deforestation is less important (dry lowlands) or even negligible (moist montane).

A preliminary pan-tropical result is given in Figure 14 which shows that the overall extent of changes are comparatively small in wet lowlands, increasing sharply in moist Lowlands, decreasing in dry lowlands and further decreasing in moist montane conditions. This pattern of change within the ecological zones seems to be relatively consistent across the tropics.

Figure 14

Changes in pan-tropic forest cover by main ecological zone: 1981-90

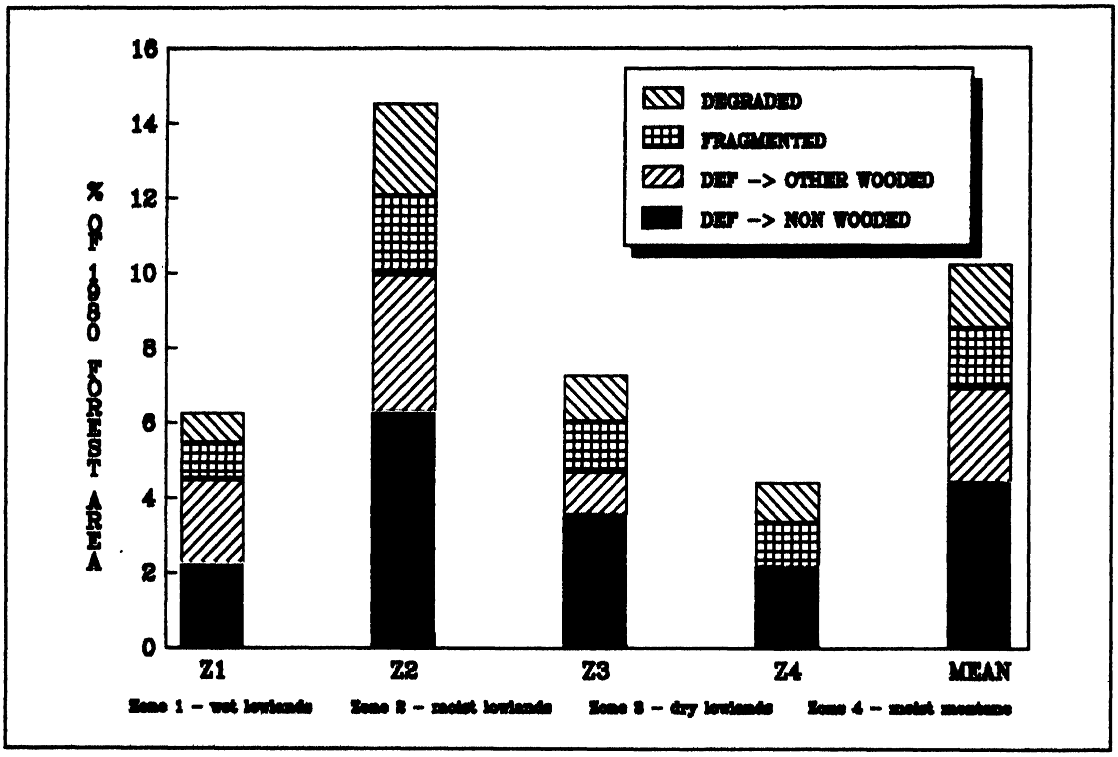
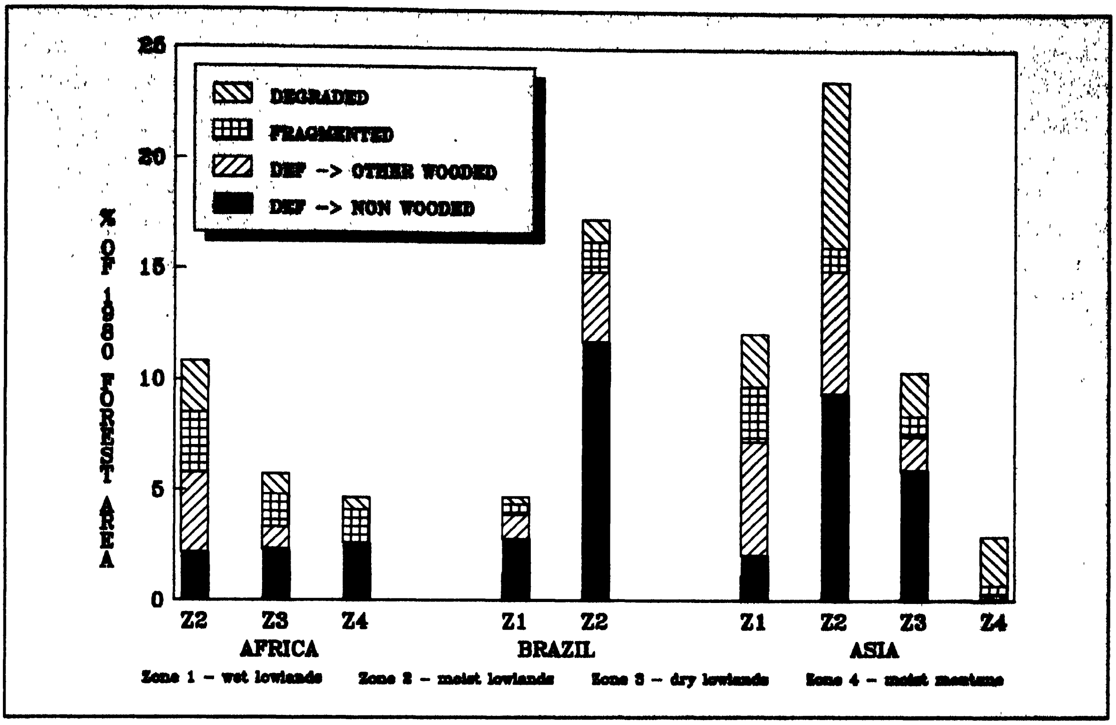


Figure 15 illustrates the ecological trend by geographical region: the higher rate of deforestation, fragmentation and degradation occurring in the moist lowland zones. A pattern similar to that observed in Africa is found in Asia and Latin America.

In both Brazil and tropical Asia change from Continuous Forest occurs at a rate much higher than in tropical Africa, probably owing to the higher population density (in Asia) and planned resettlements/resources exploitation programmes (in Brazil and Asia). It is interesting to see that in both Africa and Asia the area deforested is consistently accompanied by fragmentation and degradation processes, probably being preliminary stages to deforestation. The change process in Brazil is clearly different, where almost all the changed area is deforested, particularly to non-wooded land.

Figure 15
Forest cover changes by main ecological zone: 1981-90



3.3 Preliminary evaluation of the sampling design

The remote sensing survey was designed to be statistically sound and provide more precise estimates of forest cover and change at the regional and global levels than would be possible with the help of existing data, due to their inherent variations from country to country in data quality, inventory standards and reference dates. Further, the survey was expected to provide reliable and consistent multi-date information for modelling of changes and comprehensive information on the process of change.

The results obtained so far confirm that the level of expected precision at global and regional levels will most likely be reached as shown in Table 12.

Table 12
Initial expected and present expected standard errors of forest cover estimates

Region	Sampling units		Standard errors (%)	
	Total No.	Sample size	Initial expected	Present[1/] expected
Africa	471	47	8.0	6.1
Asia & Pacific	277	30	8.2	10.8
Latin America & Caribbean	480	40	4.7	5.4
Total	**1,228**	**117**	**3.9**	**3.8**

[1/] using information from the completed samples.

Further analysis shows that the stratification is of limited value in Africa, of some value in Asia and gives a substantial improvement in Latin America. It has been observed also that a stratification which is useful for forest cover estimation is not necessarily suitable for change estimation. In view of this different approach to reduce the sampling error, using appropriate ancillary variables in each situation has to be worked out. With proper selection of ancillary variables, the precision is expected to improve in the case of both forest cover and change estimates.

The information on the process of change provided by the sample survey is unique and most useful for policy-making. The change matrix is an invaluable tool for illustrating the future consequences for any time horizon if no action is taken to change the development of the process.

4. FOREST FRAGMENTATION

The results are given here for the West Africa and Amazon Basin subregions because they represent two interesting and contrasting fragmentation patterns:

- The West African subregion shows an advanced phase of forest depletion: the closed forest is split into several islands in a "sea" of mixed agriculture/forest fallow;

- Tn the Amazon basin deforestation is moving from the edges to the core of the main forest body. In this landscape, fragmentation is mainly represented by the complexity of the forest interface with other land cover types.

The two patterns represent different stages of demographic development : the former mature, heavily influenced by human pressure, the latter a relatively recent phase with low population pressure.

4.1 The case study in West Africa

This subregion is characterised by a very high ratio of forest fallow to closed forest even in "closed rain forest climax" ecofloristic zones and the remaining closed forest is separated into islands as shown in Figure 16.

A database with the geometrical properties of the forest islands was generated and statistics were produced at district and national level. The fragmentation was measured through the PAI.

As shown in the bar diagram (Figure 17), the PAI is well correlated with the deforestation figures estimated at national level by the Project. Note that in Liberia and Sierra Leone have been excluded due to the presence of clouds in the two countries at the time the satellite imagery was made, because this produced an apparently higher degree of fragmentation than the true values.

Figure 16
West Africa: NOAA derived forest map

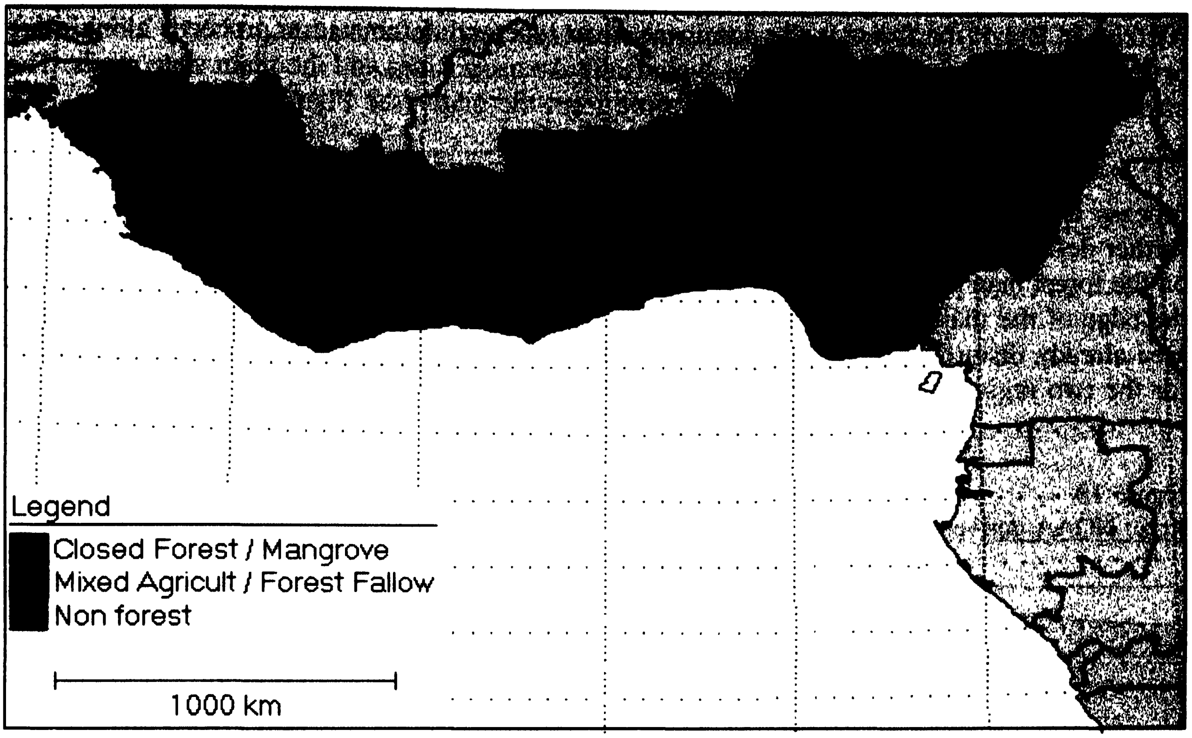
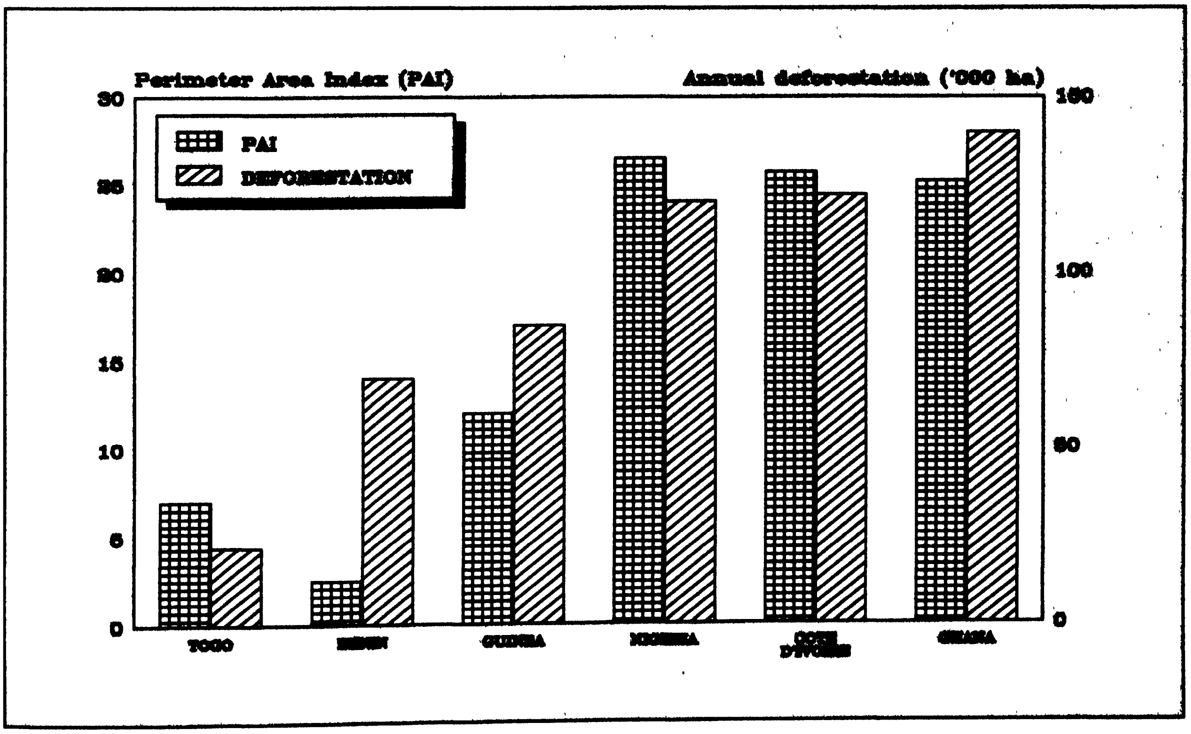


Figure 17
Fragmentation vs. deforestation, West Africa



4.2 The case study in Brazil

The two Brazilian states, Acre and Rondonia, have different landscape features to West Africa. In Brazil the forest is the dominant cover type and deforestation proceeds along more or less linear transportation corridors such as the Amazon River and the main state roads. The effects of the deforestation are clearly visible from the maps (see Figures 18 and 19).

The two states have different deforestation rates and it is interesting to analyse how this process is accompanied by the presence of zones "at risk", that are likely to be subject to further deforestation. These zones, quoted in the map legends as "edge forest", were delineated on the forest map by arbitrarily setting a buffer zone of suitable width, 10 km in this case, from the edge of the mapped forest boundaries toward the core. This forest belt or zone covers the area already disturbed, or likely to be disturbed or degraded. Spatial statistics were produced for the two regions as shown in Tables 13 and 14.

Figure 18
Acre: NOAA derived forest map

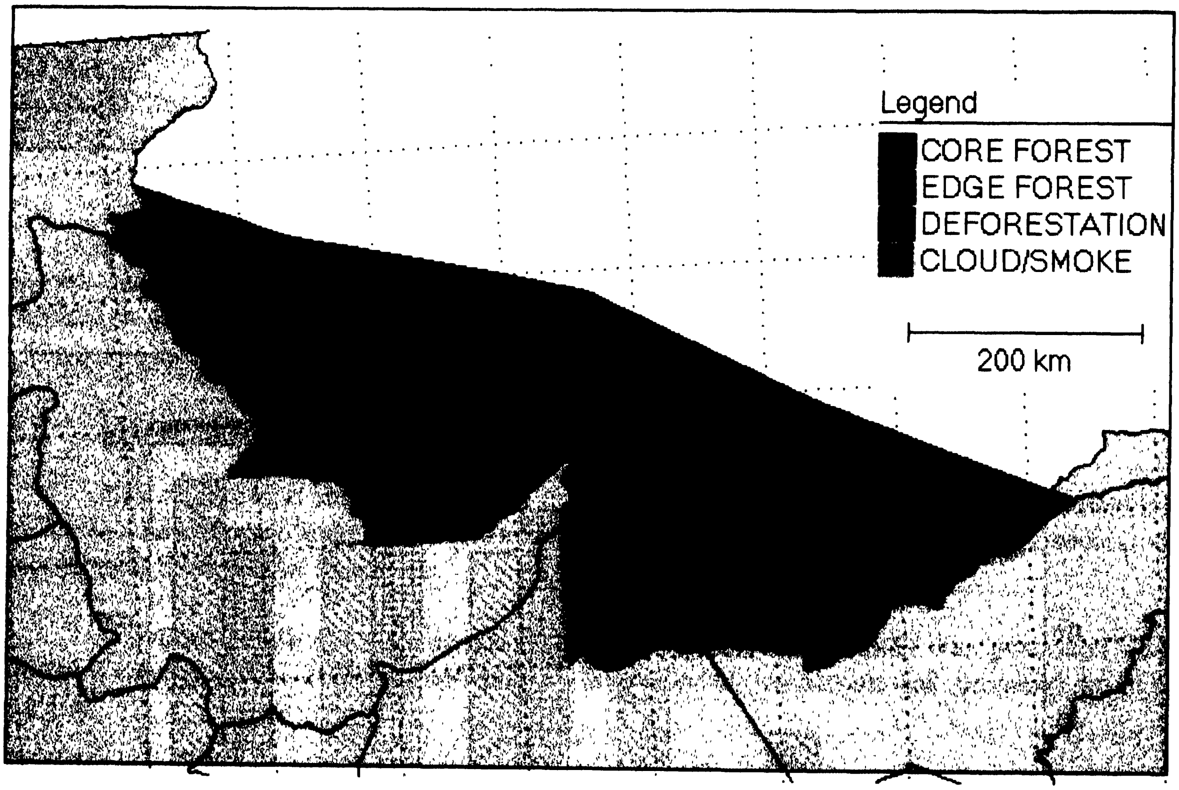


Table 13
Edge/core statistics in Acre State

Map : Acre - NOAA vegetation map		
Class	**Legend**	**Area (%)**
1	Core forest	68.82
2	Edge forest	25.16
3	Deforestation	5.72
4	Cloud/smoke	0.29
Total of four classes		**100.00**

Figure 19
Rondonia: NOAA derived forest map

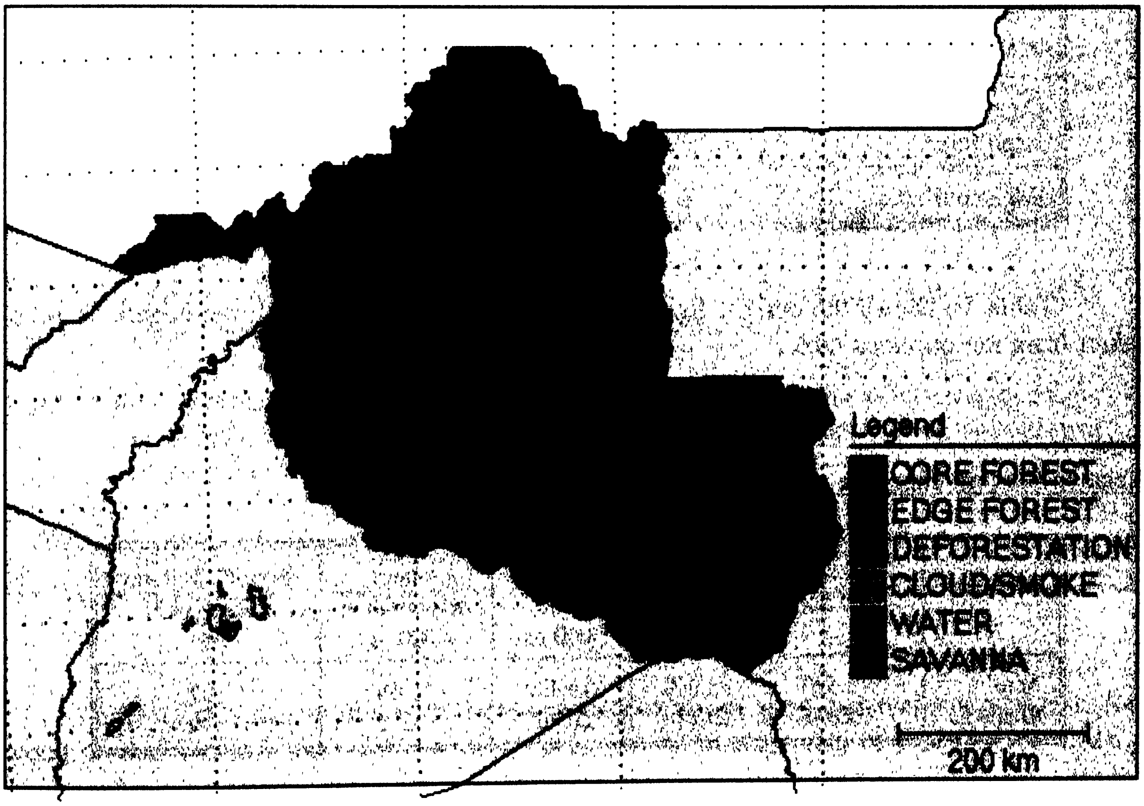


Table 14
Edge/core statistics in Rondonia State

Map : Rondonia - NOAA vegetation map		
Class	**Legend**	**Area (%)**
1	Core forest	16.33
2	Edge forest	62.60
3	Deforestation	14.06
4	Cloud/smoke	0.43
5	Water	1.31
5	Savanna	5.26
Total of six classes		**100.00**

Table 15
Edge/core ratio in Acre and Rondonia, Brazil

Forest Class	Forest region	
	Acre Area (%)	**Rondonia** Area (%)
Core forest	68.8	16.3
Edge forest	25.2	62.6
Edge/core ratio	27.0	79.0

Table 16 shows the current figures on deforestation together with the edge/core ratio taken from the previous table.

Table 16
Relation between edge/core ratio and deforestation

	Land area ('000 ha)	Forest 1980 ('000 ha)	Forest 1990 ('000 ha)	Annual deforestation ('000 ha)	Edge/Core Ratio (Edge/Total) (%)
Acre	15,370	15,098	14,422	-68	27
Rondonia	23,838	23,119	20,809	-231	79

Source: FORIS database

The annual deforestation rate in Rondonia is estimated to be about 1.1 percent of the remaining forest, while in Acre it is 0.5 percent. The edge/core analysis reveals that more than 75 percent of Rondonia's forests fall in the "edge zone", against the 25 percent in Acre. These statistics are clear indicators of the risk of further degradation of the forest resources.

Chapter V

SPECIAL STUDIES

As part of the present assessment, special studies were made on the current status of forest conservation, management of natural forests, timber harvesting and plantations. The WCMC provided inputs in the area of forest management and conservation through Tropical Managed Area Assessment 1990 Project. Based on their data the extent of legally notified forest areas for various purposes are given in Table 17.

Terminology

Conservation forest: **areas within the forestry sector designated for conservation by law or other regulations.**

Conservation area: **The term conservation area is used instead of protected area with which it is synonymous.**

Production forest (forests for wood production): **forest having terrain and soil conditions suitable for the production of wood and other products on a sustainable basis. The distance to consumption or export centres is not taken into account, which means that economically inaccessible forests are included in this class.**

Forestry sector: **that part of government responsible for the management of forest land.**

Notified forest: **forest land that is notified as reserved. N.B notified forests are usually demarcated, the boundaries being given in the notification.**

Protection forests: **areas within the forestry sector located on terrain that is too steep or rough, or subject to periods or permanent inundation, which makes forest management impractical due to physical non-productivity (FAO, 1990).**

Wildlife sector: **that part of government responsible for nature conservation.**

Forest management in a wider sense, as used here, includes management of forests for wood production, soil and water conservation as well as management of conservation areas.

Forest management could be said to begin when a forest area is demarcated and set aside to be managed for future production of forestry goods and services. Further progressive steps include: inventory of site and stand, preparation of a management plan and control, application of silvicultural treatments, all activities implying the development of the needed institutions and capacities. Thus, forest management should be considered as part of a developmental process with a goal to enhance the capacity of the forest site and stand to produce intended goods and services on a sustained and, if possible, on an increased basis.

It is worth noting that the term "protection" used in the table refers to forests set apart to conserve soil and water, whereas the term "conservation" refers to biological (e.g. wildlife) conservation. The legal notification is only the starting point of management. This must be followed by proper measures for conservation, management and development of forests.

Table 17
Extent of notified forest in the tropics classified by forest function at end 1990

Region	Land area	Wood production		Protection		Conservation		Total	
	million ha	million ha	% land area	million ha	% land area	million ha	% land area	million ha	% land area
Africa	**2,236.1**	**58.3**	**2.6**	**7.8**	**0.3**	**18.1**	**0.3**	**84.2**	**3.8**
West Sahelian Africa	528.0	16.9	3.2	5.1	1.0	1.3	0.3	23.3	4.4
East Sahelian Africa	489.7	1.6	0.3	0.1	0.0	2.3	0.3	4.0	0.8
West Africa	203.8	13.0	6.4	1.5	0.7	5.0	2.3	19.5	9.6
Central Africa	398.3	3.0	0.8	0.4	0.1	1.2	0.3	4.6	1.2
Trop. Southern and Insular Africa	616.3	23.8	3.9	0.7	0.1	8.3	1.3	32.8	5.3
Asia	**892.1**	**151.2**	**16.9**	**43.8**	**4.9**	**26.8**	**3.0**	**221.8**	**24.9**
South Asia	412.2	59.4	14.4	1.0	0.2	0.3	0.1	60.7	14.7
Continental S.E. Asia	190.1	20.1	10.6	9.7	5.1	19.8	10.4	49.6	26.1
Insular S.E. Asia	244.4	71.7	29.3	33.1	13.5	6.7	2.5	111.5	45.6
Pacific	45.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latin America	**1,650.2**	**99.9**	**6.1**	**90.1**	**5.5**	**26.4**	**1.3**	**216.4**	**13.1**
C. America & Mexico	239.6	12.0	5.0	73.2	30.6	0.8	0.8	86.0	35.9
Caribbean	69.0	0.9	1.3	0.8	1.2	0.8	1.2	2.5	3.6
Trop. South America	1,341.6	87.0	6.5	16.1	1.2	24.8	1.5	127.9	9.5
Total	**4,778.4**	**309.4**	**6.5**	**141.7**	**3.0**	**71.3**	**1.5**	**522.4**	**10.9**

1. FOREST MANAGEMENT FOR CONSERVATION

The term "conservation area" has been used instead of "protected area" and is defined as an area of land managed through legal or customary regimes so as to protect and maintain biological diversity and natural and associated cultural resources. (This definition was agreed at the IV World Congress on National Parks and Protected Areas, Caracas, 10-12 February 1992.)

Based on the survey of WCMC, Table 18 summarises the findings at regional and global levels and provides a breakdown of area by types of managing institutions, e.g. national forest administrations, national wildlife administrations and other institutions. The figures referring to the area under control of the forestry sector are obtained by adding the areas under protection and conservation.

Table 18
Number and extent of conservation areas in the forestry, wildlife and other sectors

Region	Conservation areas in forestry, wildlife and additional sectors				
	Forestry	Wildlife	Others	All	
	Area million ha	Area million ha	Area million ha	Area million ha	Land proportion %
Africa	25.9	197.7	0.6	224.2	10.0
Asia & Pacific	70.5	55.6	0.8	126.9	14.2
L. America & Caribbean	116.5	118.4	120.7	355.6	21.5
Total	**212.9**	**371.7**	**122.1**	**706.7**	**14.8**

Source: *Assessing the Conservation Status of the World's Tropical Forest;* WCMC, a contribution to the FAO FRA 1990 Project

The results of the assessment suggest that a significant proportion of the tropics is under management for conservation or protection. The quantitative information must be tempered, however, by a realistic appraisal of on-the-ground management effectiveness and the threats to existing sites. Throughout the tropics there tends to be inadequate legislation and ineffective application of the legal measures that do exist. Weak institutional support, management that is frequently deficient or even non-existent and inadequate funding are also ubiquitous. Consequently, there is a strong tendency towards 'paper parks' whose existence is largely theoretical and not reflected by substantive and durable conservation reserves on the ground. Furthermore, those sites that do exist are under increasing pressure from competing land uses.

Despite the seemingly encouraging picture that emerges from the data, it is often impossible to know whether or not a conservation area network is representative, particularly in terms of biodiversity. A special survey conducted by WCMC shows that out of 8,715 conservation areas only 5 percent are known to have been inventoried for one or more taxonomic groups. Conservation areas have frequently been established with little or no regard to ecological criteria for their selection. Continuing and growing pressure on land throughout the tropics, particularly in densely populated Asian nations, has forced the selection of conservation areas to be made on pragmatic and not necessarily scientific grounds.

2. FOREST MANAGEMENT FOR WOOD PRODUCTION

2.1 Sustainable forest management

The FAO/UNEP Forest Resources Assessment 1980 Project reported the following on the status of forest management by end 1980: Forest area under management was.about 41.3 million ha which constituted 4.3 percent of the total reported forest area. Tropical Asia contributed 39.1 million ha and of this 32.5 million ha was located in one country, i.e. India. The rest of 8.8 million ha were distributed over 18 other countries. The term forest management was used covering only wood production and implying "controlled application of harvesting regulations, complemented by appropriate silvicultural and protective measures designed to maintain and improve the productivity of the forests".

Since 1980 a number of intensive studies on forest management have been carried out by FAO (see FAO Forestry Papers No. 53,55, 88 and 89; *Unasylva* No. 156 and 159) and the International Tropical Timber Organization (ITTO). ITTO made detailed investigations on the current status of forest management and presented reports in several volumes by continent (see a summary in *No Timber without Trees*, 1989). The Project's FORIS database has collected information on a country basis.

According to an ITTO report published in 1988: "The area of tropical moist forest which is demonstrably under sustained yield management in the member countries of ITTO (excluding India) amounted, at the very most, to about one million ha and has now been reduced by about one fifth on environmental grounds. This is out of an estimated total area of some 828 million ha of productive tropical forest remaining in 1985 in all the countries in which it occurs. Under these circumstances urgent action is required, not only to ensure the proper management of previously unlogged forest, but also to assess the status of logged forest and degraded forest lands and to plan remedial action to bring these also under sustainable production as rapidly as possible".

It may be mentioned that ITTO applied strict criteria to defining the term management for sustainable timber production: that it should be practised on an operational rather than an experimental scale; that it should include the essential tools of management defining objectives, working plans, felling cycles, yield control and prediction etc.; and that it should meet the wider political, social and economic criteria without which sustainability is probably uncertain.

As South Asia was a major subregion to account for managed area, a survey made by Forest Survey of India (FSI) was used as a reliable source of information. According to the State of Forest Report (1987), 59 million out of 75 million ha of land area under the control of the Forest Department were covered by working plans. Although, by and large, prescriptions of the working plans have been adhered to, it has been possible to secure adequate natural regeneration in only about 15 percent of the area covered by the working plans.

The reason is that grazing could not be controlled and forests could not be adequately protected from fire. In over 60 percent of area covered by the working plans, the annual cut exceeded the increment on account of unauthorised fellings, mostly for firewood.

The reports of ITTO and FSI present a bleaker picture of natural forest management in 1990 than in 1980. However, some positive developments may be interesting to note. In Malaysia, after transfer of intensively managed lowland Dipterocarp forests to other uses, (notably oil palm plantations and agriculture), efforts have been initiated to bring hill Dipterocarp forests under management. For this purpose an area of approximately 9.8 million ha has been set apart as permanent forest reserve for wood production. In Indonesia bans on log exports combined with development of local wood-based industry and setting of production reserves are expected to promote integrated forestry and forest industry development.

In India the Forest Conservation Act 1980 (with amendment made in 1988) had a salutary effect in slowing down the pace of deforestation. Logging bans in several parts of the country combined with a vigorous drive to raise agro-forestry plantations is expected to reduce the pressure on natural forests. There is, however, need for direct investment to rehabilitate and intensively manage the natural forests.

Initiatives to manage natural forests on a sustained basis are also reported in Ghana, Cameroon, Côte d'Ivoire and the Central African Republic.

In Mexico approximately 5.5 million ha are reported to be under management where silvicultural treatments are being applied to improve the growing stock. In South America several pilot scale applications have been reported (*Unasylva* No. 169) which could provide directions for development of forest management in the region.

2.2 Forest harvesting

Historical trend. The study of trends in timber harvesting was carried out by the Project in cooperation with the Forest Products Division of FAO Forestry Department using the FORIS database.

Figure 20 illustrates the trends in annual production of non-coniferous industrial roundwood (sawlogs and veneer logs) in the three tropical regions from 1961 to 1990. There is levelling off in Africa, slightly but steadily increasing in Latin America and the Caribbean and steeply and steadily increasing in Asia and the Pacific.

Table 19 provides information on harvesting intensity and harvested areas by region. All three regions (see Figure 21) exhibit a slow but steady increase in the share of harvesting operations that occur in secondary forest. This effect is due partly to the fact that less primary forest remains each year, but it also results partly from the fact that changing markets increasingly improve the economic feasibility of re-logging areas that were harvested two or more decades previously. This is especially true with respect to the increase in market acceptability of "lesser known" tree species. Although the increase is seldom dramatic, it is relatively steady and over a period of decades the effect is significant.

Figure 20

Trends in average annual production of non-coniferous industrial roundwood
(sawlogs and veneer logs only) in the three major regions of the tropics, 1961-90

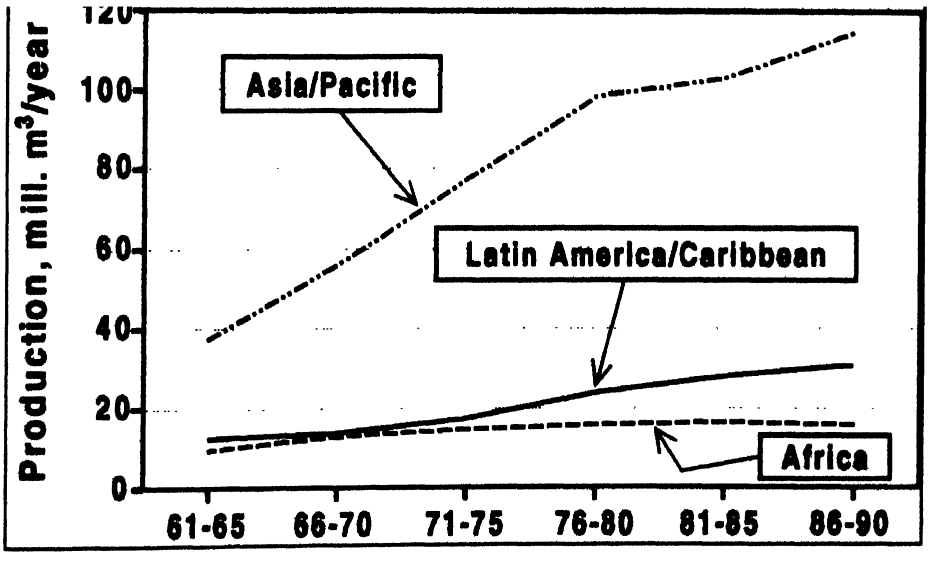


Table 19

Estimated harvesting intensities and areas of broadleaved forest harvested annually in the three major regions of the tropics, 1961-90

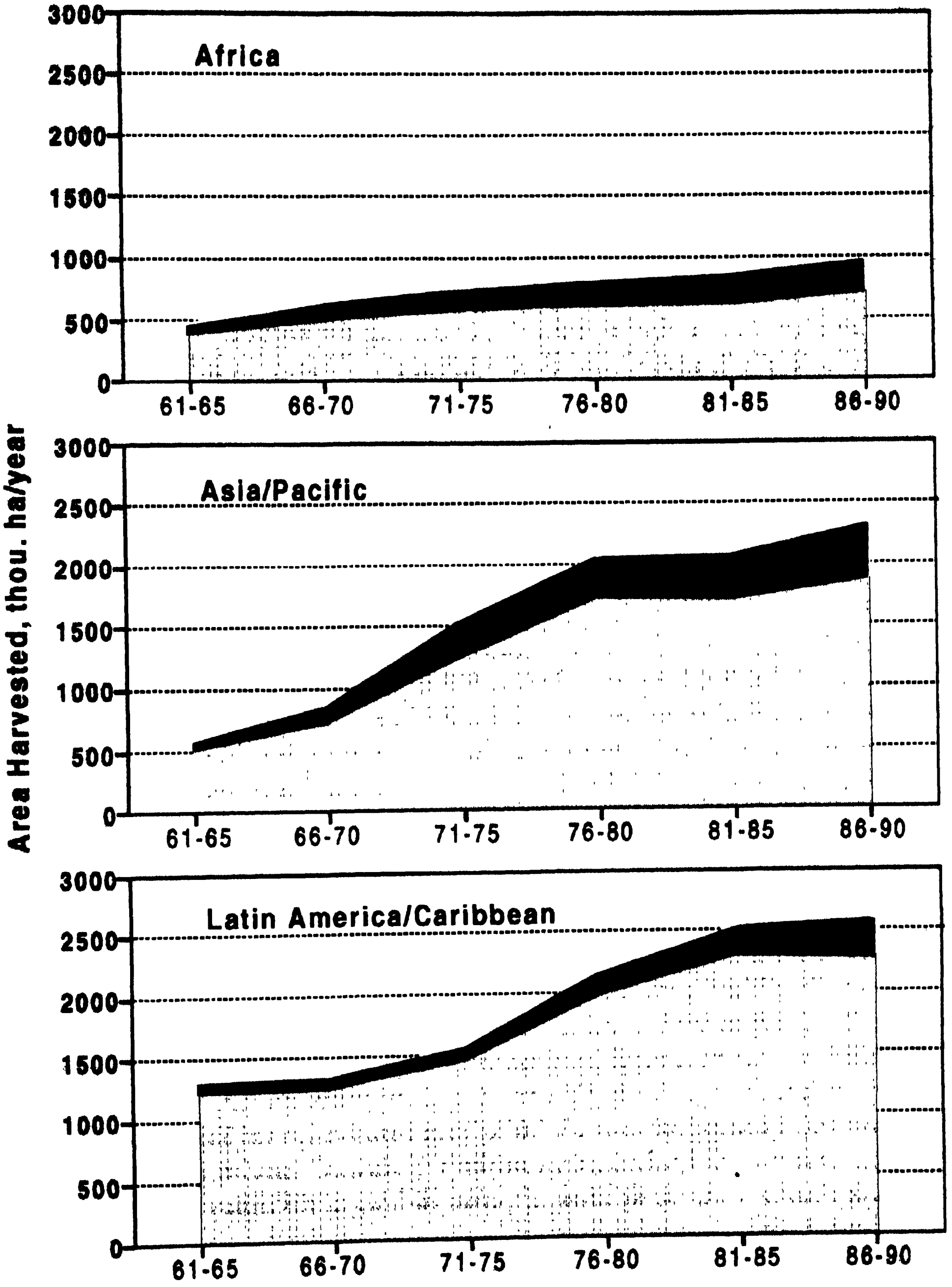
	Africa			Asia and the Pacific			Latin America and the Caribbean			All tropical countries		
	Average harvest intensity (m^3/ha)	Area of forest harvested annually ('000 ha)		Average harvest intensity (m^3/ha)	Area of forest harvested annually ('000 ha)		Average harvest intensity (m^3/ha)	Area of forest harvested annually ('000 ha)		Average harvest intensity (m^3/ha)	Area of forest harvested annually ('000 ha)	
Period		Primary forest	Secondary forest		Primary forest	Secondary forest		Primary forest	Secondary forest		Primary forest	Secondary forest
61-65	14	394	91	42	510	78	7	1,247	57	17	2,152	226
66-70	14	506	137	43	750	135	8	1,260	76	20	2,516	348
71-75	14	593	166	35	1,343	221	8	1,485	119	20	3,422	505
76-80	14	612	215	33	1,732	319	8	2,011	183	19	4,356	717
81-85	14	634	239	32	1,718	369	8	2,297	251	18	4,648	859
86-90	13	723	248	33	1,861	453	8	2,287	320	19	4,871	1,020

Table 19 and Figure 21 read together illustrate regional differences in the annual area harvested and the stocking density of commercial species. As an example, even though the *volume* of non-coniferous sawlogs and veneer logs produced annually in the Asia and Pacific region during 1986 to 1990 was 3.7 times the comparable volume produced in the Latin America and Caribbean region, the estimated *total area harvested* in tropical Asia is only 89 percent of that in tropical America. This is due to the fact that the average commercial timber harvest volume per unit area in the Asia and Pacific region during 1986 to 1990 is estimated to be about 33 m^3/ha compared to an average of only about 8 m^3/ha in the Latin America and Caribbean region.

Impact of timber harvesting on stand and site

Impacts associated with industrial timber harvesting in the tropics. Timber harvesting in the tropics, as in the temperate regions, is an inherently disruptive activity that intentionally changes the structure of the forest and can also significantly affect environmental values and non-timber forest resources. The impacts associated with harvesting are generally of two types: those that affect the stand which is intended to remain after the harvesting has been completed and those that affect the site itself.

Figure 21
Estimated areas of tropical closed broadleaved forests harvested annually in the three major regions of the tropics. The grey shaded portion refers to the primary forests and the blue to the secondary forests.



Stand Impacts

(i) Felling. Studies reviewed from all three major regions of the tropics suggest that between one-tenth and one-third of the advance regeneration and residual trees are commonly knocked over or broken during felling operations. Although this is a higher level of damage than would be expected, for instance, in temperate mixed forests, it appears on the whole to be relatively constant over time. However, studies suggest that felling damage tends to increase in proportion to the intensity of harvest, measured as the volume of timber removed per hectare. Thus, efforts to promote increased utilisation of "lesser-known" species in the future could have the undesirable side effect of increasing also the amount of damage directly attributable to felling operations.

(ii) Extraction. In all three major tropical regions, transport of felled tree stems from the stump to a landing where they can be loaded onto trucks is accomplished primarily with ground-skidding equipment. Studies show that on the whole, damage by skidding equipment to advance regeneration and residual trees tends to be as high or higher than that caused by the felling operation. Again, studies support a conclusion that the percentage of trees damaged or destroyed tends to increase as the intensity of harvest increases. On the basis of regional averages, the intensity of harvest has remained almost constant in all three major tropical regions since 1961. Keeping in view the fact that by 1990 the average area of closed broadleaved tropical forest harvested annually was 9.1 million hectares, compared to an average of only 4.0 million hectares harvested annually in 1961. Even so, this increase of 230 percent in the *area* harvested annually occurred during a period when the *volume* harvested annually was increasing by 265 percent.

Site Impacts. Most site impacts associated with logging operations in the tropics can be attributed to skidtrails or to haul roads, and for the most part these are soil-related impacts. A certain amount of site damage can occur when trees are felled, especially if they fall into streams or other sensitive areas. However, most soil disturbance and compaction within the stand itself results from the skidding operation, and nearly all soil erosion that results from timber harvesting is associated with roads.

Data from a variety of studies carried out over a span of several decades indicate rather strongly that soil disturbance associated with skidding operations tends to increase with increasing harvest intensity. Whereas early studies (e.g. Nicholson 1958) typically reported disturbed soils covering 10-15 percent of harvested areas, more recent studies (Schmitt 1989, FAO 1989, Costa Filho 1991) have reported disturbance levels in the range of 20-25 percent of the area harvested. This suggests that the total area of soil disturbed by harvesting operations in the closed broadleaved forests of the tropics is now approaching 2.3 million hectares annually. This is an area amounting to nearly 60 percent of the area actually harvested in 1961, and is probably three or four times the total area of soils that were disturbed annually by harvesting operations around 1961.

3. FOREST PLANTATIONS

Terminology

Plantations are defined as:

- **forest stands established artificially by afforestation on land which previously did not carry forests; or**
- **forest stands established artificially by reforestation on land which carried forest within the previous 50 years or within living memory and involving the replacement of the previous crop by a new and essentially different crop.**

They are distinguished according to function:

- **Industrial plantations are established totally or partly for production of wood for industry mainly as sawlogs and veneerlogs, pulpwood and pitprops.**
- **Non-industrial plantations are established mainly for one or several of the following objectives.**
  - **Production of fuelwood or wood for charcoal (possibly as industrial energy source)**
  - **Production of small wood for domestic consumption (in particular rural plantation)**
  - **Non-wood products and soil protection.**

The above definitions are consistent with FAO/UNEP Forest Resources Assessment 1980.

The study on forest plantations was conducted by the Project in cooperation with the Department of Forest Survey of the Swedish Royal College of Forestry. A detailed technical report is being separately published on which the following presentation is based.

3.1 Methodology

Establishment of the *time series data* of forestry plantations by country in a tabular form was the first step in the study, and formed the basis for reported area assessment. Available country reports were used as the main data source. Consistency was checked between different years of reports for each country. Since plantation areas for most of the countries were reported at 1989 or earlier, the data for 1990 were estimated in most of the cases on the basis of trend of annual plantation during previous years or planned plantation for 1990 and onwards.

The sources quoted in the time series data table refer to the plantation areas in the reference years and only in a few cases to the species composition. Additional references given in the case of a few countries were used to estimate areas occupied by main species.

The information about *species composition* of plantations is quite inadequate especially in the countries where large scale plantations are being established under community forestry. Composition of the main species was, therefore, estimated based on other reports, articles and in a few cases the composition as determined during previous years. Distinguishing *industrial* from *non-industrial* plantation proved to be particularly difficult in some countries due to ambiguous reporting and variation in classification. In such cases the UNEP/FAO assessment of 1980 (country brief) or other sources were used as a basis. Plantations established under community forestry were classified as non-industrial.

In order to assess the *annual plantation rate* during 1981 to 1990 at subregional, regional or global levels, the plantation area for each country was estimated at the reference year 1980, on the basis of time series data. Where time series data were inadequate for making a good reference year estimate, the area reported by FAO in 1980 was used if found to match with the general trend within the country. To arrive at reported plantation area figures at global, regional and subregional levels, total area, and area by end use and species, a "bottom to top" approach was followed treating the country as a study unit.

Estimation was done using available information on both **reported** and **net** plantation areas from plantation inventory and survival reports to derive a regression function. While reviewing the inventory reports it was found that some of the reports quote only the area actually determined (net area) through the inventory and not the reported area originally planted. In such cases, reported areas were estimated or extracted from the country reports. Similarly, where reports gave only survival percentage, net planted area was derived by multiplying reported area with survival percentage.

For estimation of net planted area, inventory results were treated as sample observations. The regression line between reported and net areas was drawn only to show the trend at global level and not for estimating the areas at regional or country levels. Estimation of total net planted areas and net annual plantation rates at global and regional levels were done independently.

3.2 Results

According to this study the total plantation area reported in 90 countries of the tropical zone amounts to a total of 43.8 million ha as at the end of 1990 (country-wise figures are given in Annex 1 and a region-wise summary in Table 20). Tropical Asia and the Pacific has the largest share with 73 percent and the remainder is distributed between tropical America (20 percent) and tropical Africa (7 percent). The five countries having the largest reported area under plantation, constituting about 85 percent of the tropical plantations, are India (18.9 million ha), Indonesia (8.8 million ha), Brazil (7.0 million ha), Vietnam (2.1 million ha) and Thailand (0.8 million ha).

Table 20

Reported and net forest plantation areas in the tropics at 1990 (in '000 ha)

Region	No. of countries under assessment	Reported plantation area at 1990			Estimated net plantation area	Area planted annually	
		Industrial plantations	Non-industrial plantations	Total reported area		Reported	Estimated net
Africa	40	1,400	1,600	3,000	2,100	130	90
Asia & Pacific	17	9,100	23,100	32,200	22,600	2,100	1,470
Latin America & Caribbean	33	5,100	3,500	8,600	6,000	370	260
Total	**90**	**15,600**	**28,200**	**43,800**	**30,700**	**2,610**	**1,820**

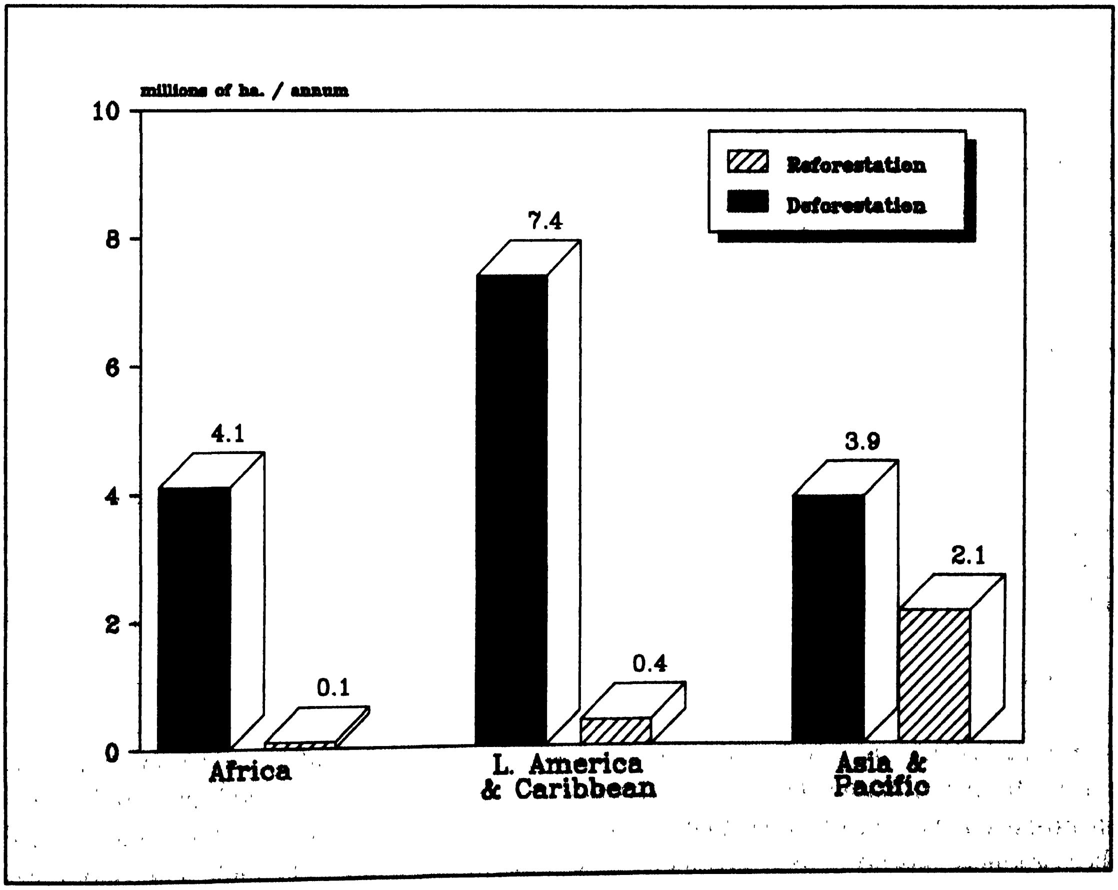
Source: FORIS database

During 1981 to 1990 there has been considerable development in non-industrial plantations in the form of tree planting and by agroforestry. Cultivation of trees with agricultural crops and growing woodlots outside gazetted forests has gained momentum in the last decade. In order to estimate the planted area outside the traditional forests, many countries have fixed ad hoc criteria to convert the number of seedlings raised in the nurseries and distributed or planted, into area. No entirely consistent estimate can be made at global level for these forms of tree planting.

Survival rates calculated from 56 plantation inventories of 18 tropical countries were used to determine the average rate at global level at about 70 percent. Applying this latter factor to the reported plantation area gives a net total plantation area in the tropics of 30.7 million ha as at end 1990.

About 60 percent of the reported plantations were established during 1981 to 1990, in other words the increase in plantation area during the ten years over the estimate of 1980 is about 150 percent. The average area planted annually in the tropics reported during the decade 1981 to 1990 was about 2.60 million ha, corresponding to a net plantation area of 1.82 million ha. Thus the ratio between the annual rate of deforestation and forest plantation is 1:8.5. Region-wise comparative figures are given in Figure 22.

Figure 22
Annual deforestation and reforestation rates of the period 1981-90, by region



3.3 Species composition

Area information at the species level in plantations is very scarce. In a few cases, there is also an element of uncertainty in the actual name of the species due to hybridisation and unknown seed source. Generally speaking, countries report plantation areas by genus/species group, and in many cases only the name of the main species used in plantations, without indicating the area and end use for this species. As a result assessment of area occupied by species and end use is subject to large uncertainty. Tentative estimates of plantation areas (million ha) under the main genus/species group in the tropics to the end of 1990 are given in Table 21.

Table 21
Estimates of reported areas of the main species (million ha)

Regions / Species	Eucalypts	Pines	Teak	Acacias	Others	Total
Tr. Africa	0.79	0.61	0.145	0.25	1.2	3
Tr. America	4.07	2.78	0.015	-	1.77	8.6
Tr. Asia & Pacific	5.20	1.20	2.03	3.15	20.62	32.2
Total	**10.06**	**4.59**	**2.19**	**3.40**	**23.59**	**43.8**
Percentage	**23.0**	**10.5**	**5.0**	7.7	**53.8**	**100.0**

3.4 Monitoring and evaluation

The study shows that the monitoring of the state of forest plantations is very limited in tropical countries. About four-fifths the of the current plantations have never been surveyed. The analysis of the available plantation inventory reports confirm that the actual area of forestry plantations is significantly less than the area reported.

A general tendency has been observed to **overestimate the yield while preparing plantation feasibility reports**. The actual yield obtained from plantations is generally much lower, often less than 50 percent, than the yield initially estimated. The principal factors for the low yield are wrong choice of the species on a given site, wrong site selection for a given species and lack of tending operations. Due to the increased emphasis on the target area to be covered, matching species with the planting site is often ignored or neglected. Most plantations have suffered from poor stocking due to initial casualty of seedlings and their non-replacement, illegal felling and damage due to grazing and fire. Non-application of fertilizer, recommended in a few cases to overcome the deficiency of soil nutrient, has also resulted in low productivity.

Barring a few exceptions, plantations suffer from **lack of integrated planning**. There is no match between what is required and what is produced. The spatial and temporal locations have not been kept in view to minimise the cost of production leading to a very paradoxical situation. In one situation there is a deficiency of fuelwood but pulpwood and sawlogs have been produced with heavy investment without pulp and saw mills. In other situations, the timber producer has no market guarantee to sell his produce at an economically viable price. Industrial plantations established near fuelwood deficit population centres could not be protected against illicit felling.

There appears to be a strong and urgent need to create national level plantation databanks to bridge the existing knowledge gap about growth and yield and site/species relationship of the plantations. Besides the research results based on permanent sample plots, the results of plantation inventories and reliable data on actual yield from harvested plantations can be pooled at one focal institution in each country and computerised. In addition to characteristics of plantations such as species, density, rotation and yield information about site factors such as climatic variables, soil conditions and local biotic factors, both human and animal, and brief history of plantations (damage due to fire, pests, disease and other factors) must be recorded to make the plantation data useful.

Such an information centre will not only help the country concerned but also other countries whose forestry research institutions are weaker and who have less experience in plantation forestry. There is a great hope that by organising and sharing the existing knowledge, there will be a major advancement in the plantation forestry.

3.5 Non-forest plantations

Non-forest plantations have become a potential source of wood due to increasing demand and improved technology. Area information about non-forest plantations is available essentially for tropical Asia (Indonesia, Malaysia and Thailand) which contains most of the non-forest plantations of the tropical world (as is confirmed by the fact that about 85 percent of the world's production of rubber, coconut oil and palm oil comes from this region - *FAO Production Yearbook 1991*). Of the total area of 14 million ha, 7.2 million ha are occupied by rubber and the remainder by coconut (4.2 million ha) and oil palm (2.7 million ha).

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COUNTRY TABLES

This section provides assessment results at country level and the basic background information on derivation of the results. Below is a listing of the table headings. Each Table consists of 3 parts, one for each region, namely (a) Africa, (b) Asia and the Pacific and (c) Latin America and the Caribbean. At the end of the third part is the grand total for all regions.

These tables contain standardised country figures obtained by re-appraising the country information following the definition, classification and the reference date accepted for the global assessment. This is necessary because inventory specifications generally differ from country to country. The standardisation is required to secure a consistent global picture. **It is not intended to replace the original country information which remain a unique source of reference.**

The thematic content of the country tables are the following:

1. Socio-economic data
2 State of forest inventory
3. Area of natural forests and plantations
4. Forest area change during 1981-90
5. Forest harvesting
6. Land area and forest cover by ecological zone
7. Area of forest formations
8. Annual deforestation during 1981-90 by forest formations

As mentioned in the chapter on methodology, the updating of results in the present system of assessment is an almost continuous process. A new set of global tropical tables can be produced at suitable intervals incorporating all available new data combined with existing information. In fact, new and improved information is already available for some of the countries just after finalisation of the current set of tables. These new data, and others which will become available in due course, will be included in FORIS and used in improving the model and processing of the updated results.

Table 1 shows selected socio-economic indicators of the countries studied including land area, population and gross national product. The land area reported is taken from the FAO Production Yearbook. Population data were obtained from FAO Statistics Division, and GNP data from World Bank statistics.

Table 2 describes the state of forest inventory. For each country the total number of national forest surveys/inventories, the reference date used as baseline and the reliability classes of state and change assessment are reported. The surveys listed here are the existing and reliable information on forest cover that were available to FRA 1990 by end of February 1992. The reference years reported refer to actual dates of the imagery used and not to the date of publication of the results. Three reliability classes used are (1) High, (2) Average, and (3) Low which are defined as follows:

STATE ASSESSMENT:

Reliability 1 : Forest inventories based on high resolution satellite data (LANDSAT TM, SPOT) or aerial photos, supplemented by extensive field checking or sample survey.

Reliability 2 : Forest inventories based on medium resolution satellite data (typically LANDSAT MSS) with limited ground truthing.

Reliability 3 : Surveys or maps based on heterogeneous material like vegetation maps, land use surveys, etc. generally at coarse resolution and often out of date. The reliability class 3 is synonym of insufficient information and need for a reliable baseline in future.

CHANGE ASSESSMENT:

Reliability 1 : This class is assigned to the countries for which two or more comparable (in terms of classification of the forest types) inventories exist, and the observed forest change is used to perform a 'local fit' of the model parameters. For this class the model is used merely as an adjustment function for standardising the reference dates to 1980 and 1990.

Reliability 2 : This class is assigned to the countries for which some partially reliable multi-date observations are available, which are used to control the model estimates.

Reliability 3 : Countries with no reliable multi-date information. The estimate of change is based on model(s).

Table 3 provides the natural forest and plantation areas at end 1990 and the estimated biomass for natural forests by country and subregion. The natural forest area for the standard reference year 1990 was calculated using the most recent reliable inventory for each subnational unit as a baseline. The model was then used as adjustment function to extrapolate the results for 1990. The results at subnational level were finally totalled by country. The table shows the forest area at end 1990 in thousands of ha, the percentage of land covered with forests and the hectares of forest per capita.

The areas of plantations have been derived from a special study carried out by the project in cooperation with the Royal college of Forestry, Umeå, Sweden. Also for plantations the land cover percentage and the hectares per capita are shown. Due to the small magnitude of the figures for plantations, the per capita values are expressed in hectares per thousands inhabitants.

The table also shows total forest biomass, average biomass per hectare and per capita. The forest biomass presented in the table refers to Total Above Ground Biomass (TAGB) and it was calculated using the Volume Over Bark (VOB) data contained in the FORIS 1980 and FORIS 1990 volume data. The VOB is the volume per hectare of all the stems with dbh greater or equal to 10 centimeters over bark. The average VOB per hectare is then converted to TAGB using appropriate expansions factors. The average per ha and total values of TAGB were computed separately for closed and open forest formations and the per hectare values tabulated represent weighted averages.

Table 4 relates to the forest cover change data (1981 to 1990) and gives natural forest cover for the standard reference years 1980 and 1990, the area annually deforested in thousands of ha, the annual rate of change, at compound rate, and the deforestation per capita using the average population of the decade. Similarly, for forest plantations the area in 1990, the area annually planted, the rate of change and the per capita values are reported. Finally the ratio between area annually deforested and planted is given. This column is left blank when the ratio can not be calculated because one or both values are equal to zero or negative or very small.

Table 5 provides information on forest harvesting of closed broadleaved forests including average logging intensity, total area annually logged divided into areas previously logged and newly logged and the fraction of total closed broadleaved forests annually logged.

Table 6 presents the land area and total forest cover by ecological zone. For each country, the six ecological zones are reported, together with their respective land area and forest cover. The scope of this table is to contrast the present versus the potential vegetation. The natural forest area has been classified into six main ecological zones using GIS techniques.

Table 7 gives the breakdown of the forest cover in 1990 by ecological zones. For each country and subregion/region the forest formation area is reported. The forest formations are defined according to the potential vegetation classes derived from ecological zones map. The percentage values indicate the relative importance of each forest formation in a geographical region.

Table 8 provides the break-down of annual deforestation by forest formations. The area deforested annually in each formation class and the share of total deforestation of the geographical region are listed.

le 1a: Socio-economic data

REGION: AFRICA

YEAR: 1990

Country	Land area	Population				Gross National Product	
	000 ha	Total 1990	Density 1990	Annual growth 1981-90		Per capita 1990	Annual Growth 1981-90
		000 inh.	inh./km²	000 inh./year	%	US$/capita	%
URKINA FASO	27380	9007	32.9	205	2.6	330	1.3
APE VERDE	403	379	94.1	8	2.5	680	2.2
HAD	125920	5679	4.5	120	2.4	180	3.8
AMBIA	1000	858	85.8	22	3.0	340	-0.1
UINEA-BISSAU	2812	950	33.8	15	1.7	180	1.3
ALI	122019	9362	7.7	234	2.9	200	0.1
AURITANIA	102522	2024	2.0	47	2.7	500	-1.8
IGER	126670	7109	5.6	180	3.0	310	-4.1
ENEGAL	19253	7369	38.3	170	2.7	710	0.0
EST SAHELIAN AFRICA	**527979**	**42738**	**8.1**	**1001**	**2.7**	**352**	**-0.4**
IBOUTI	2318	427	18.4	12	3.3	n.a.	n.a.
THIOPIA	110100	46744	42.5	799	1.9	120	-1.6
ENYA	56969	25130	44.1	850	4.2	370	0.3
OMALIA	62734	7257	11.6	180	2.9	150	1.5
UDAN	237600	25195	10.6	651	3.0	400	-2.4
GANDA	19955	18442	92.4	532	3.5	180	3.3
AST SAHELIAN AFRICA	**489676**	**123195**	**25.2**	**3025**	**2.9**	**239**	**-0.5**
ENIN	11062	4741	42.9	125	3.1	360	-1.1
OTE D'IVOIRE	31800	12596	39.6	427	4.2	750	-3.4
HANA	23002	15020	65.3	429	3.4	390	-0.3
UINEA	24586	6876	28.0	147	2.4	440	0.0
BERIA	9675	2554	26.4	70	3.2	580	0.0
GERIA	91077	108949	119.6	2400	2.5	290	-1.7
ERRA LEONE	7162	4151	58.0	89	2.4	250	-1.3
OGO	5439	3455	63.5	90	3.1	410	-1.7
EST AFRICA	**203803**	**158341**	**77.7**	**3776**	**2.8**	**351**	**-1.5**
AMEROON	46540	10376	22.3	250	2.8	480	-1.0
ENTRAL AFRICAN REP.	62298	2913	4.7	61	2.4	390	-1.5
ONGO	34150	1994	5.8	47	2.7	1000	-0.2
QUATORIAL GUINEA	2805	342	12.2	6	1.9	340	3.4
ABON	25767	1171	4.5	36	3.8	3550	-4.2
AIRE	226760	35990	15.9	961	3.2	220	-1.6
ENTRAL AFRICA	**398320**	**52786**	**13.3**	**1362**	**3.0**	**385**	**-1.8**
NGOLA	124670	10020	8.0	230	2.6	n.a.	n.a.
OTSWANA	56673	1285	2.3	38	3.6	2230	5.8
URUNDI	2565	5451	212.5	135	2.9	210	1.4
ALAWI	9408	8428	89.6	234	3.3	200	0.1
OZAMBIQUE	78409	15663	20.0	356	2.6	80	-3.6
AMIBIA	82329	1330	1.6	33	2.9	1475	1.6
WANDA	2467	7232	293.1	207	3.4	310	-2.6
ANZANIA	88604	27328	30.8	846	3.8	110	-1.1
AMBIA	74339	8456	11.4	272	4.0	420	-2.9
MBABWE	38667	9721	25.1	258	3.1	650	0.2
ROPICAL S. AFRICA	**558131**	**94915**	**17.0**	**2609**	**3.3**	**283**	**-0.3**
ADAGASCAR	58154	11980	20.6	320	3.2	230	-2.4
SULAR AFRICA	**58154**	**11980**	**20.6**	**320**	**3.2**	**230**	**-2.4**
OTAL	**2236063**	**483954**	**21.6**	**12093**	**2.9**	**.311**	**-1.1**

Table 1b: Socio-economic data

REGION: ASIA AND THE PACIFIC **YEAR:** 1990

Country	**Land area**	**Population**				**Gross National Product**	
	000 ha	Total 1990	Density 1990	Annual growth 1981-90		Per capita 1990	Annual Growth 1981-90
		000 inh.	inh./km^2	000 inh./year	%	US$/capita	%
BANGLADESH	13017	115594	888.0	2737	2.7	210	1.9
BHUTAN	4700	1427	30.4	26	2.0	190	6.8
INDIA	297319	853373	287.0	16452	2.2	360	3.3
NEPAL	13680	19143	139.9	429	2.6	180	2.1
PAKISTAN	77088	122666	159.1	3737	3.7	400	3.2
SRI LANKA	6463	17209	266.3	239	1.5	470	2.5
SOUTH ASIA	**412267**	**1129412**	**274.0**	**23620**	**2.4**	**347**	**3.2**
CAMBODIA	17652	8246	46.7	185	2.6	170	0.0
LAOS	23080	4071	17.6	87	2.4	200	1.2
MYANMAR	65797	41675	63.3	785	2.1	n.a.	n.a.
THAILAND	51089	55702	109.0	898	1.8	1420	5.9
VIETNAM	32549	67171	206.4	1347	2.3	n.a.	n.a.
CONTINENT. S.E. ASIA	**190167**	**176864**	**93.0**	**3302**	**2.1**	**1195**	**5.6**
BRUNEI	527	266	50.5	8	3.7	n.a.	n.a.
INDONESIA	181157	180514	99.6	2956	1.8	560	3.9
MALAYSIA	32855	17339	52.8	358	2.3	2330	2.9
PHILIPPINES	29817	62409	209.3	1409	2.6	730	-1.2
SINGAPORE	61	2712	4445.9	30	1.2	11088	4.8
INSULAR S. E. ASIA	**244417**	**263240**	**107.7**	**4760**	**2.0**	**826**	**2.6**
PAPUA NEW GUINEA	45286	4011	8.9	93	2.7	850	-0.7
PACIFIC	**45286**	**4011**	**8.9**	**93**	**2.7**	**850**	**-0.7**
TOTAL	**892137**	**1573527**	**176.4**	**31774**	**2.3**	**474**	**3.1**

Table 1c: Socio-economic data

REGION: LATIN AMERICA AND THE CARIBBEAN **YEAR:** 1990

Country	Land area	Population				Gross National Product	
	000 ha	Total 1990	Density 1990	Annual growth 1981-90		Per capita 1990	Annual Growth 1981-90
		000inh.	inh./km^2	000 inh./year	%	US$/capita	%
COSTA RICA	5106	3015	59.0	73	2.8	1900	1.0
EL SALVADOR	2085	5252	251.9	73	1.5	1000	-0.3
GUATEMALA	10843	9197	84.8	228	2.9	910	-1.8
HONDURAS	11189	5138	45.9	148	3.4	640	-0.7
MEXICO	190869	88598	46.4	1818	2.3	2490	-0.5
NICARAGUA	11875	3871	32.6	110	3.4	420	-4.6
PANAMA	7599	2418	31.8	46	2.1	1900	-1.8
CENTRAL AMERICA	**239566**	**117488**	**49.0**	**2496**	**2.4**	**2123**	**-0.6**
ANTIGUA AND BARBUDA	44	76	172.7	0	0.1	4290	30.7
BAHAMAS	1001	260	26.0	4	1.5	11550	1.3
BELIZE	2280	182	8.0	4	2.3	1960	2.5
CUBA	10982	10324	94.0	59	0.6	n.a.	n.a.
DOMINICA	75	82	109.3	1	1.2	2220	4.6
DOMINICAN REPUBLIC	4838	7170	148.2	147	2.3	830	-0.2
FRENCH GUYANA	8815	92	1.0	2	2.9	n.a.	n.a.
GRENADA	34	85	250.0	-2	-2.3	2130	7.1
GUADELOUPE	169	340	201.2	1	0.4	n.a.	n.a.
GUYANA	19685	1040	5.3	18	1.9	380	-4.2
HAITI	2756	6504	236.0	109	1.9	370	-2.4
JAMAICA	1083	2521	232.8	35	1.5	1500	-0.3
MARTINIQUE	106	341	321.7	2	0.5	n.a.	n.a.
PUERTO RICO	886	3480	392.8	28	0.8	6356	1.4
ST. KITTS AND NEVIS	36	51	141.7	0	-0.2	3540	6.0
ST. LUCIA	61	150	245.9	3	2.3	2099	1.4
ST. VINCENT	39	116	297.4	2	1.6	1710	4.8
SURINAME	15600	403	2.6	5	1.3	3350	-4.5
TRINIDAD AND TOBAGO	513	1283	250.1	19	1.6	3460	-5.2
CARIBBEAN SUBREGION	**69003**	**34501**	**50.0**	**436**	**1.4**	**1931**	**-0.6**
BOLIVIA	108438	7314	6.7	174	2.8	630	-2.0
BRAZIL	845651	150368	17.8	2908	2.2	2680	0.4
COLOMBIA	103870	31819	30.6	603	2.1	1258	1.2
ECUADOR	27684	10782	38.9	266	2.9	953	-0.3
PARAGUAY	39730	4277	10.8	113	3.1	1090	-0.8
PERU	128000	22332	17.4	504	2.6	1100	-2.6
VENEZUELA	88205	19736	22.4	471	2.8	2560	-1.5
TROPICAL S. AMERICA	**1341578**	**246627**	**18.4**	**5039**	**2.3**	**2180**	ε
TOTAL	**1650147**	**398616**	**24.2**	**7970**	**2.3**	**2148**	**-0.2**
GRAND TOTAL	**4778347**	**2456097**	**51.4**	**51837**	**2.4**	**720**	**0.9**

Notes: - numbers may not tally due to rounding
- ε indicates a very small value
- n.a. indicates that no data are available; sub-totals and totals were computed excluding the missing numbers

Table 2a: State of forest inventory

REGION: AFRICA **YEAR**: 1990

Country	Number of national forest surveys/inventories			Survey used as baseline		Change assessment
	Total	Before 1981	Years 1981-90 (inclusive)	Reference year	Reliability class	Reliability class
ANGOLA	1	1	0	1974	2	3
BENIN	1	1	0	1975	2	3
BOTSWANA	1	0	1	1987	2	3
BURKINA FASO	1	1	0	1980	3	3
BURUNDI	1	1	0	1977	2	3
CAMEROON	1	1	0	1975-87	2	3
CAPE VERDE	1	0	1	1980-88	3	3
CENTRAL AFRICAN REP.	1	0	1	1982	2	3
CHAD	0	0	0	1980	3	3
CONGO	1	1	0	1967	3	3
COTE D'IVOIRE	2	1	1	1987	1	2
DJIBOUTI	1	0	1	1985	2	3
EQUATORIAL GUINEA	1	0	1	1990	1	3
ETHIOPIA	1	1	0	1975	3	3
GABON	1	1	0	1970	3	3
GAMBIA	1	1	0	1980	1	3
GHANA	1	1	0	1980-87	3	3
GUINEA	1	1	0	1980-88	2	3
GUINEA-BISSAU	1	1	0	1976	2	3
KENYA	1	1	0	1976	3	3
LIBERIA	1	0	1	1981	2	3
MADAGASCAR	1	1	0	1973-76	2	3
MALAWI	1	0	1	1990	2	3
MALI	1	0	1	1988	1	3
MAURITANIA	1	1	0	1980	3	3
MOZAMBIQUE	1	1	0	1972	2	3
NAMIBIA	1	1	0	1980	3	3
NIGER	1	1	0	1977	2	3
NIGERIA	1	1	0	1976	2	3
RWANDA	2	0	2	1987	1	2
SENEGAL	1	1	0	1978	2	3
SIERRA LEONE	1	1	0	1976	2	3
SOMALIA	0	0	0	1980	3	3
SUDAN	1	0	1	1983	3	3
TANZANIA	1	1	0	1972-81	2	3
TOGO	1	1	0	1975	2	3
UGANDA	0	0	0	1980	3	3
ZAIRE	1	0	1	1976-84	2	3
ZAMBIA	1	0	1	1984	2	3
ZIMBABWE	1	0	1	1985	3	3

Notes: - the vegetation map of Africa, compiled by ICIV for FRA 1990 has been used as one assessment with reference year 1980 for the countries where no surveys or inventories were available.

Table 2b: State of forest inventory

REGION: ASIA AND THE PACIFIC **YEAR**: 1990

Country	Number of national forest surveys/inventories			Survey used as baseline		Change assessment
	Total	Before 1981	Years 1981-90 (inclusive)	Reference year	Reliability class	Reliability class
BANGLADESH	1	0	1	1984	2	2
BHUTAN	1	1	0	1978	2	3
BRUNEI	1	0	1	1984	2	3
CAMBODIA	2	1	1	1989	1	2
INDIA	3	0	3	1988	1	2
INDONESIA	1	0	1	1982	2	2
LAOS	2	1	1	1989	1	1
MALAYSIA	2	1	1	1982-87	1	1
MYANMAR	2	1	1	1989	2	2
NEPAL	2	2	0	1979	2	1
PAKISTAN	1	0	1	1990	2	3
PAPUA NEW GUINEA	1	0	1	1990	3	3
PHILIPPINES	2	1	1	1988	2	1
SINGAPORE	1	0	1	1987	2	1
SRI LANKA	2	1	1	1983	2	1
THAILAND	5	3	2	1987	2	1
VIETNAM	2	1	1	1987	2	2

Table 2c: State of forest inventory

REGION: LATIN AMERICA AND THE CARIBBEAN **YEAR: 1990**

Country	Number of national forest surveys/inventories			Survey used as baseline		Change assessment
	Total	Before 1981	Years 1981-90 (inclusive)	Reference year	Reliability class	Reliability class
ANTIGUA AND BARBUDA	1	1	0	1980	2	3
BAHAMAS	1	0	1	1986	2	3
BELIZE	1	1	0	1979	2	3
BOLIVIA	1	1	0	1975	2	3
BRAZIL	2	1	1	1981-91	2	2
COLOMBIA	1	1	0	1980	1	3
COSTA RICA	3	1	2	1987	1	1
CUBA	1	0	1	1990	1	3
DOMINICA	1	0	1	1984	2	3
DOMINICAN REPUBLIC	1	0	1	1983	2	3
ECUADOR	1	0	1	1987	1	3
EL SALVADOR	1	1	0	1975	2	3
FRENCH GUYANA	1	1	0	1973	3	3
GRENADA	1	0	1	1982	2	3
GUADELOUPE	1	0	1	1985	2	3
GUATEMALA	2	1	1	1988	2	2
GUYANA	1	1	0	1975	3	3
HAITI	2	2	0	1977	2	3
HONDURAS	2	1	1	1986	2	2
JAMAICA	2	1	1	1985	2	2
MARTINIQUE	1	1	0	1974	2	3
MEXICO	1	1	0	1970-86	2	3
NICARAGUA	1	1	0	1979	3	2
PANAMA	2	1	1	1986	1	2
PARAGUAY	3	2	1	1980-85	2	2
PERU	1	1	0	1975	1	3
PUERTO RICO	2	1	1	1985	1	1
ST. KITTS AND NEVIS	1	1	0	1980	2	3
ST. LUCIA	1	0	1	1982	2	3
ST. VINCENT	1	0	1	1984	2	3
SURINAME	1	1	0	1970	3	3
TRINIDAD AND TOBAGO	1	1	0	1980	2	3
VENEZUELA	1	1	0	1977	1	3

Notes:
- numbers may not tally due to rounding
- ε indicates a very small value
- n.a. indicates that no data are available; sub-totals and totals were computed excluding the missing numbers
- the reference year may vary according different sub-national units

Table 3a: Area in natural forests and plantations

REGION: AFRICA **YEAR: 1990**

Country	Natural forests						Plantations		
	Forest cover			Forest biomass			Area		
	000 ha	% land area	ha/ capita	000 t	tons / ha	tons / capita	000 ha	% land area	ha/ 000 capita
BURKINA FASO	4416	16.1	0.5	349197	79	39	28	0.1	3.1
CAPE VERDE	6	1.6	ε	960	150	3	14	3.5	36.9
CHAD	11434	9.1	2.0	717588	63	126	6	ε	1.1
GAMBIA	97	9.7	0.1	9619	100	11	1	0.1	1.4
GUINEA-BISSAU	2021	71.9	2.1	166987	83	176	1	ε	1.5
MALI	12144	10.0	1.3	749542	62	80	20	ε	2.1
MAURITANIA	554	0.5	0.3	34992	63	17	3	ε	1.7
NIGER	2550	2.0	0.4	82257	32	12	17	ε	2.4
SENEGAL	7544	39.2	1.0	517203	69	70	160	0.8	21.7
WEST SAHELIAN AFRICA	**40768**	**7.7**	**1.0**	**2628345**	**65**	**62**	**251**	**ε**	**5.9**
DJIBOUTI	22	1.0	0.1	1872	84	4	0	0.0	0.0
ETHIOPIA	14165	12.9	0.3	2038626	144	44	270	0.2	5.8
KENYA	1187	2.1	ε	112650	95	5	168	0.3	6.7
SOMALIA	754	1.2	0.1	76584	102	11	6	ε	0.8
SUDAN	42976	18.1	1.7	2647934	62	105	290	0.1	11.5
UGANDA	6346	31.8	0.3	376582	59	20	28	0.1	1.5
EAST SAHELIAN AFRICA	**65450**	**13.4**	**0.5**	**5254247**	**80**	**43**	**762**	**0.2**	**6.2**
BENIN	4947	44.7	1.0	198116	40	42	20	0.2	4.2
COTE D'IVOIRE	10904	34.3	0.9	870158	80	69	90	0.3	7.1
GHANA	9555	41.5	0.6	817031	86	54	75	0.3	5.0
GUINEA	6692	27.2	1.0	559110	84	81	5	ε	0.7
LIBERIA	4633	47.9	1.8	1049465	227	411	8	0.1	2.9
NIGERIA	15634	17.2	0.1	1615756	103	15	216	0.2	2.0
SIERRA LEONE	1889	26.4	0.5	200192	106	48	8	0.1	1.9
TOGO	1353	24.9	0.4	99104	73	29	24	0.4	6.9
WEST AFRICA	**55607**	**27.3**	**0.4**	**5408931**	**97**	**34**	**445**	**0.2**	**2.8**
CAMEROON	20350	43.7	2.0	2951434	145	284	23	ε	2.2
CENTRAL AFRICAN REP.	30562	49.1	10.5	3808777	125	1308	9	ε	3.1
CONGO	19865	58.2	10.0	5466398	275	2741	53	0.2	26.6
EQUATORIAL GUINEA	1826	65.1	5.3	480264	263	1404	0	0.0	0.0
GABON	18235	70.8	15.6	5118484	281	4373	30	0.1	25.6
ZAIRE	113275	50.0	3.1	28523205	252	793	60	ε	1.7
CENTRAL AFRICA	**204112**	**51.2**	**3.9**	**46348562**	**227**	**878**	**175**	**ε**	**3.3**
ANGOLA	23074	18.5	2.3	1624865	70	162	171	0.1	17.1
BOTSWANA	14261	25.2	11.1	546189	38	425	1	ε	0.8
BURUNDI	233	9.1	ε	16053	69	3	132	5.1	24.2
MALAWI	3486	37.1	0.4	485699	139	58	180	1.9	21.4
MOZAMBIQUE	17329	22.1	1.1	1383784	80	88	40	0.1	2.6
NAMIBIA	12569	15.3	9.4	481400	38	362	0	0.0	0.0
RWANDA	164	6.6	ε	26938	164	4	125	5.1	17.3
TANZANIA	33555	37.9	1.2	1445320	43	53	220	0.2	8.1
ZAMBIA	32301	43.5	3.8	2273175	70	269	68	0.1	8.0
ZIMBABWE	8897	23.0	0.9	540198	61	56	120	0.3	12.3
TROPICAL S. AFRICA	**145868**	**26.1**	**1.5**	**8823621**	**61**	**93**	**1057**	**0.2**	**11.1**
MADAGASCAR	15782	27.1	1.3	1680293	107	140	310	0.5	25.9
INSULAR AFRICA	**15782**	**27.1**	**1.3**	**1680293**	**107**	**140**	**310**	**0.5**	**25.9**
TOTAL	**527586**	**23.6**	**1.1**	**70143999**	**133**	**145**	**3000**	**0.1**	**6.2**

Table 3b: Area in natural forests and plantations

REGION: ASIA AND THE PACIFIC **YEAR: 1990**

Country	Natural forest						Plantations		
	Forest cover			Forest biomass			Area		
	000 ha	% land area	ha/ capita	000 t	tons / ha	tons / capita	000 ha	% land area	ha/ 000 capita
BANGLADESH	769	5.9	ε	104219	136	1	335	2.6	2.9
BHUTAN	2809	59.8	2.0	508127	181	356	5	0.1	3.5
INDIA	51729	17.4	0.1	4805690	93	6	18900	6.4	22.1
NEPAL	5023	36.7	0.3	548711	109	29	80	0.6	4.2
PAKISTAN	1855	2.4	ε	203156	110	2	240	0.3	2.0
SRI LANKA	1746	27.0	0.1	197742	113	12	198	3.1	11.5
SOUTH ASIA	**63931**	**15.5**	**0.1**	**6367645**	**100**	**6**	**19758**	**4.8**	**17.5**
CAMBODIA	12163	68.9	1.5	2162861	178	262	0	0.0	0.0
LAOS	13173	57.1	3.2	2544111	193	625	6	ε	1.5
MYANMAR	28856	43.9	0.7	6258866	217	150	335	0.5	8.0
THAILAND	12735	24.9	0.2	1585345	125	29	756	1.5	13.6
VIETNAM	8312	25.5	0.1	1523569	183	23	2100	6.5	31.3
CONTINENT. S.E. ASIA	**75240**	**39.6**	**0.4**	**14074752**	**187**	**80**	**3197**	**1.7**	**18.1**
BRUNEI	458	87.0	1.7	135519	296	510	0	0.0	0.0
INDONESIA	109549	60.5	0.6	22261392	203	123	8750	4.8	48.5
MALAYSIA	17583	53.5	1.0	4590947	261	265	116	0.4	6.7
PHILIPPINES	7831	26.3	0.1	1848390	236	30	290	1.0	4.6
SINGAPORE	4	7.2	ε	880	200	0	0	0.0	0.0
INSULAR S. E. ASIA	**135426**	**55.4**	**0.5**	**28837128**	**213**	**110**	**9156**	**3.7**	**34.8**
PAPUA NEW GUINEA	36000	79.5	9.0	6890346	191	1718	43	0.1	10.6
PACIFIC	**36000**	**79.5**	**9.0**	**6890346**	**191**	**1718**	**43**	**0.1**	**10.6**
TOTAL	**310597**	**34.8**	**0.2**	**56169872**	**181**	**36**	**32153**	**3.6**	**20.4**

Table 3c: Area of natural forests and plantations

REGION: LATIN AMERICA AND THE CARIBBEAN **YEAR:** 1990

Country	Natural forest						Plantations		
	Forest cover			Forest biomass			Area		
	000 ha	% land area	ha/ capita	000 t	tons / ha	tons / capita	000 ha	% land area	ha/ 000 capita
COSTA RICA	1428	28.0	0.5	261909	184	87	40	0.8	13.3
EL SALVADOR	123	5.9	ε	11627	94	2	6	0.3	1.1
GUATEMALA	4225	39.0	0.5	725485	172	79	40	0.4	4.3
HONDURAS	4605	41.2	0.9	527274	115	103	4	ε	0.7
MEXICO	48586	25.5	0.5	3173608	65	36	155	0.1	1.7
NICARAGUA	6013	50.6	1.6	1088136	181	281	20	0.2	5.1
PANAMA	3117	41.0	1.3	695380	223	288	9	0.1	3.6
CENTRAL AMERICA	**68096**	**28.4**	**0.6**	**6483420**	**95**	**55**	**273**	**0.1**	**2.3**
ANTIGUA AND BARBUDA	10	22.3	0.1	1176	120	16	0	0.0	0.0
BAHAMAS	186	18.5	0.7	22260	120	86	0	0.0	0.0
BELIZE	1996	87.6	11.0	255019	128	1401	3	0.1	16.5
CUBA	1715	15.6	0.2	209022	122	20	350	3.2	33.9
DOMINICA	44	58.8	0.5	5292	120	65	0	0.0	0.0
DOMINICAN REPUBLIC	1077	22.3	0.2	106330	99	15	10	0.2	1.4
FRENCH GUYANA	7997	90.7	86.9	2499846	313	27172	0	0.0	0.0
GRENADA	6	16.2	0.1	660	120	8	0	0.3	1.2
GUADELOUPE	93	54.7	0.3	11100	120	33	0	0.0	0.0
GUYANA	18416	93.6	17.7	4571492	248	4396	12	0.1	11.5
HAITI	23	0.8	ε	2330	100	0	12	0.4	1.8
JAMAICA	239	22.1	0.1	43182	181	17	21	1.9	8.3
MARTINIQUE	43	40.4	0.1	5136	120	15	0	0.0	0.0
PUERTO RICO	321	36.2	0.1	38460	120	11	4	0.5	1.1
ST. KITTS AND NEVIS	13	36.7	0.3	1584	120	31	0	0.0	0.0
ST. LUCIA	5	7.4	ε	540	120	4	0	0.0	0.0
ST. VINCENT	11	26.9	0.1	1260	120	11	0	0.0	0.0
SURINAME	14768	94.7	36.6	3830633	259	9496	12	0.1	29.7
TRINIDAD AND TOBAGO	155	30.2	0.1	32566	210	25	18	3.4	13.6
CARIBBEAN	**47115**	**68.3**	**1.4**	**11637886**	**247**	**337**	**442**	**0.6**	**12.8**
BOLIVIA	49317	45.5	6.7	7376206	150	1009	40	ε	5.5
BRAZIL	561107	66.4	3.7	106053416	189	705	7000	0.8	46.6
COLOMBIA	54064	52.0	1.7	10514556	195	330	180	0.2	5.7
ECUADOR	11962	43.2	1.1	2354632	197	218	64	0.2	5.9
PARAGUAY	12859	32.4	3.0	795571	62	186	13	ε	3.0
PERU	67906	53.1	3.0	16013646	236	717	263	0.2	11.8
VENEZUELA	45690	51.8	2.3	8615377	189	437	362	0.4	18.3
TROPICAL S. AMERICA	**802904**	**59.8**	**3.3**	**151723404**	**189**	**615**	**7922**	**0.6**	**32.1**
TOTAL	**918115**	**55.6**	**2.3**	**169844710**	**185**	**426**	**8636**	**0.5**	**21.7**
GRAND TOTAL	**1756297**	**36.8**	**0.7**	**296158580**	**169**	**121**	**43789**	**0.9**	**17.8**

Notes:
- numbers may not tally due to rounding
- ε indicates a very small value

Table 4a: Forest area change during 1981 - 1990

REGION: AFRICA **YEAR**: 1990

Country	Land area	Natural forests				Plantations			
	000 ha	Total 1990	Annual deforestation 1981-1990			Total 1990	Annual plantation 1981-1990		
		000 ha	000 ha	ha/ 000 capita	%	000 ha	000 ha	ha/ 000 capita	%
BURKINA FASO	27380	4416	32	4.0	-0.7	28	1.6	0.2	8.8
CAPE VERDE	403	6	0	0.0	0.0	14	1.0	3.0	13.3
CHAD	125920	11434	89	17.4	-0.7	6	0.3	ε	5.5
GAMBIA	1000	97	1	1.1	-0.8	1	ε	ε	1.8
GUINEA-BISSAU	2812	2021	16	18.1	-0.8	1	0.1	0.1	13.3
MALI	122019	12144	106	13.0	-0.8	20	1.9	0.2	31.4
MAURITANIA	102522	554	0	0.0	0.0	3	0.3	0.2	23.9
NIGER	126670	2550	0	0.0	0.0	17	1.1	0.2	11.0
SENEGAL	19253	7544	52	8.0	-0.7	160	14.8	2.3	29.0
WEST SAHELIAN AFRICA	**527979**	**40768**	**295**	**7.8**	**-0.7**	**251**	**21.0**	**0.6**	**19.8**
DJIBOUTI	2318	22	0	0.0	0.0	0	0.0	0.0	0.0
ETHIOPIA	110100	14165	39	0.9	-0.3	270	17.2	0.4	10.6
KENYA	56969	1187	7	0.3	-0.6	168	2.3	0.1	1.5
SOMALIA	62734	754	3	0.4	-0.4	6	-0.5	-0.1	-5.9
SUDAN	237600	42976	482	22.0	-1.1	290	12.5	0.6	5.8
UGANDA	19955	6346	65	4.1	-1.0	28	0.0	0.0	0.0
EAST SAHELIAN AFRICA	**489676**	**65450**	**595**	**5.5**	**-0.9**	**762**	**31.5**	**0.3**	**5.5**
BENIN	11062	4947	70	16.9	-1.3	20	0.8	0.2	5.2
COTE D'IVOIRE	31800	10904	119	11.4	-1.0	90	4.5	0.4	7.2
GHANA	23002	9555	137	10.7	-1.3	75	1.5	0.1	2.3
GUINEA	24586	6692	87	14.1	-1.2	5	0.2	ε	4.7
LIBERIA	9675	4633	25	11.5	-0.5	8	ε	ε	0.4
NIGERIA	91077	15634	119	1.2	-0.7	216	5.3	0.1	2.8
SIERRA LEONE	7162	1889	12	3.3	-0.6	8	0.2	0.1	3.3
TOGO	5439	1353	22	7.3	-1.5	24	1.7	0.6	13.1
WEST AFRICA	**203803**	**55607**	**591**	**4.2**	**-1.0**	**445**	**14.2**	**0.1**	**3.9**
CAMEROON	46540	20350	122	13.4	-0.6	23	1.7	0.2	14.4
CENTRAL AFRICAN REP.	62298	30562	129	49.6	-0.4	9	0.9	0.3	33.5
CONGO	34150	19865	32	18.3	-0.2	53	3.6	2.1	12.2
EQUATORIAL GUINEA	2805	1826	7	22.3	-0.4	0	0.0	0.0	0.0
GABON	25767	18235	116	117.8	-0.6	30	1.1	1.1	4.7
ZAIRE	226760	113275	732	23.5	-0.6	60	3.8	0.1	10.3
CENTRAL AFRICA	**398320**	**204112**	**1139**	**24.8**	**-0.5**	**175**	**11.0**	**0.2**	**10.4**
ANGOLA	124670	23074	174	19.6	-0.7	171	1.4	0.2	0.9
BOTSWANA	56673	14261	77	70.3	-0.5	1	0.1	0.1	14.9
BURUNDI	2565	233	1	0.3	-0.6	132	11.3	2.4	21.1
MALAWI	9408	3486	53	7.2	-1.4	180	10.0	1.4	8.4
MOZAMBIQUE	78409	17329	135	9.7	-0.7	40	1.4	0.1	4.4
NAMIBIA	82329	12569	43	37.0	-0.3	0	0.0	0.0	0.0
RWANDA	2467	164	0	0.1	-0.3	125	6.1	1.0	6.9
TANZANIA	88604	33555	438	19.0	-1.2	220	12.2	0.5	8.5
ZAMBIA	74339	32301	363	51.1	-1.1	68	3.0	0.4	6.0
ZIMBABWE	38667	8897	61	7.2	-0.7	120	2.0	0.2	1.8
TROPICAL S. AFRICA	**558131**	**145868**	**1345**	**16.4**	**-0.9**	**1057**	**47.4**	**0.6**	**6.1**
MADAGASCAR	58154	15782	135	13.0	-0.8	310	4.4	0.4	1.5
INSULAR AFRICA	**58154**	**15782**	**135**	**13.0**	**-0.8**	**310**	**4.4**	**0.4**	**1.5**
TOTAL	**2236063**	**527586**	**4100**	**9.7**	**-0.7**	**3000**	**129.5**	**0.3**	**5.8**

Table 4b: Forest area change during 1981 - 1990.

REGION: ASIA AND THE PACIFIC YEAR: 1990

Country	Land area	Natural forests				Plantations			
	000 ha	Total 1990	Annual deforestation 1981-1990			Total 1990	Annual plantation 1981-1990		
		000 ha	000 ha	ha/ 000 capita	%	000 ha	000 ha	ha/ 000 capita	%
BANGLADESH	13017	769	38	0.4	-3.9	335	17.5	0.2	7.7
BHUTAN	4700	2809	16	12.7	-0.6	5	0.3	0.2	9.6
INDIA	297319	51729	339	0.4	-0.6	18900	1441.4	1.9	15.5
NEPAL	13680	5023	54	3.2	-1.0	80	6.1	0.4	15.5
PAKISTAN	77088	1855	77	0.7	-3.4	240	6.0	0.1	2.9
SRI LANKA	6463	1746	27	1.7	-1.4	198	8.6	0.5	5.9
SOUTH ASIA	**412267**	**63931**	**551**	**0.5**	**-0.8**	**19758**	**1479.9**	**1.5**	**14.8**
CAMBODIA	17652	12163	131	17.9	-1.0	0	0.0	0.0	0.0
LAOS	23080	13173	129	35.6	-0.9	6	0.2	0.1	4.1
MYANMAR	65797	28856	401	10.6	-1.3	335	27.9	0.7	19.6
THAILAND	51089	12735	515	10.1	-3.3	756	42.0	0.8	8.5
VIETNAM	32549	8312	137	2.3	-1.5	2100	70.0	1.2	4.1
CONTINENT. S.E. ASIA	**190167**	**75240**	**1314**	**8.2**	**-1.6**	**3197**	**140.1**	**0.9**	**5.9**
BRUNEI	527	458	2	8.0	-0.4	0	0.0	0.0	0.0
INDONESIA	181157	109549	1212	7.3	-1.0	8750	474.0	2.9	8.1
MALAYSIA	32855	17583	396	25.5	-2.0	116	9.0	0.6	16.1
PHILIPPINES	29817	7831	316	5.7	-3.3	290	-1.0	-ε	-0.3
SINGAPORE	61	4	0	0.0	0.0	0	0.0	0.0	0.0
INSULAR S. E. ASIA	**244417**	**135426**	**1926**	**8.0**	**-1.3**	**9156**	**482.0**	**2.0**	**7.8**
PAPUA NEW GUINEA	45286	36000	113	31.9	-0.3	43	2.1	0.6	6.8
PACIFIC	**45286**	**36000**	**113**	**31.9**	**-0.3**	**43**	**2.1**	**0.6**	**6.8**
TOTAL	**892137**	**310597**	**3904**	**2.8**	**-1.2**	**32153**	**2104.1**	**1.5**	**11.2**

Table 4c: Forest area change during 1981 - 1990.

REGION: LATIN AMERICA AND THE CARIBBEAN **YEAR: 1990**

Country	Land area	Natural forests				Plantations			
	000 ha	Total 1990	Annual deforestation 1981-1990			Total 1990	Annual plantation 1981-1990		
		000 ha	000 ha	ha/ 000 capita	%	000 ha	000 ha	ha/ 000 capita	%
COSTA RICA	5106	1428	50	18.7	-2.9	40	3.7	1.4	30.5
EL SALVADOR	2085	123	3	0.6	-2.2	6	0.5	0.1	14.9
GUATEMALA	10843	4225	81	10.1	-1.7	40	2.5	0.3	10.3
HONDURAS	11189	4605	112	25.4	-2.1	4	0.4	0.1	ε
MEXICO	190869	48586	678	8.5	-1.3	155	7.5	0.1	6.8
NICARAGUA	11875	6013	124	37.3	-1.9	20	1.8	0.6	31.2
PANAMA	7599	3117	64	29.4	-1.9	9	0.5	0.2	8.2
CENTRAL AMERICA	**239566**	**68096**	**1112**	**10.6**	**-1.5**	**273**	**16.9**	**0.2**	**10.1**
ANTIGUA AND BARBUDA	44	10	0	0.3	-0.2	0	0.0	0.0	0.0
BAHAMAS	1001	186	4	18.5	-2.1	0	0.0	0.0	0.0
BELIZE	2280	1996	5	30.6	-0.2	3	0.1	0.3	1.8
CUBA	10982	1715	17	1.7	-1.0	350	19.3	1.9	8.3
DOMINICA	75	44	0	4.1	-0.7	0	0.0	0.0	0.0
DOMINICAN REPUBLIC	4838	1077	35	5.4	-2.8	10	0.4	0.1	5.8
FRENCH GUYANA	8815	7997	0	3.4	ε	0	0.0	0.0	0.0
GRENADA	34	6	0	-2.0	4.3	0	ε	0.1	ε
GUADELOUPE	169	93	0	0.9	-0.3	0	0.0	0.0	0.0
GUYANA	19685	18416	18	18.9	-0.1	12	1.1	1.1	25.9
HAITI	2756	23	1	0.2	-4.8	12	1.1	0.2	28.2
JAMAICA	1083	239	27	11.4	-7.2	21	0.8	0.3	5.1
MARTINIQUE	106	43	0	0.7	-0.5	0	0.0	0.0	0.0
PUERTO RICO	886	321	-4	-1.3	1.4	4	0.1	ε	2.9
ST. KITTS AND NEVIS	36	13	0	-0.4	0.2	0	0.0	0.0	0.0
ST. LUCIA	61	5	0	2.4	-5.2	0	0.0	0.0	0.0
ST. VINCENT	39	11	0	2.3	-2.1	0	0.0	0.0	0.0
SURINAME	15600	14768	13	33.5	-0.1	12	0.4	0.9	3.5
TRINIDAD AND TOBAGO	513	155	4	3.1	-2.1	18	0.2	0.1	0.9
CARIBBEAN	**69003**	**47115**	**122**	**3.8**	**-0.3**	**442**	**23.4**	**0.7**	**7.8**
BOLIVIA	108438	49317	625	97.0	-1.2	40	1.4	0.2	4.4
BRAZIL	845651	561107	3671	27.0	-0.6	7000	279.2	2.1	5.2
COLOMBIA	103870	54064	367	12.7	-0.7	180	12.7	0.4	13.0
ECUADOR	27684	11962	238	25.2	-1.8	64	2.1	0.2	4.0
PARAGUAY	39730	12859	403	108.5	-2.7	13	1.0	0.3	15.8
PERU	128000	67906	271	13.7	-0.4	263	12.6	0.6	6.7
VENEZUELA	88205	45690	599	34.5	-1.2	362	23.8	1.4	11.3
TROPICAL S. AMERICA	**1341578**	**802904**	**6174**	**27.9**	**-0.7**	**7922**	**332.7**	**1.5**	**5.6**
TOTAL	**1650147**	**918115**	**7407**	**20.6**	**-0.8**	**8636**	**373.0**	**1.0**	**5.8**
GRAND TOTAL	**4778347**	**1756297**	**15411**	**7.0**	**-0.8**	**43789**	**2606.5**	**1.2**	**9.5**

Notes: - numbers may not tally due to rounding
- ε indicates a very small value

Table 5a: state of logging 1990

REGION: AFRICA **YEAR**: 1990

Country	Forest area			Closed broadleaved forest						
	Total	Closed broadleaved forest		Average logging intensity	Annually logged area 1981-1990					
					Newly logged		Previously logged		Total logged area	
									000 ha	% of total closed broadleaved forest area
	000 ha	000 ha	%	m³/ha	000 ha	%	000ha	%		
BURKINA FASO	4416	252	5.7	5	0	0.0	0	100.0	0	0.00
CHAD	11434	423	3.7	5	0	80.6	0	19.4	0	0.00
GAMBIA	97	39	40.0	18	0	0.0	0	100.0	0	1.10
GUINEA-BISSAU	2021	803	39.7	5	5	90.4	1	9.6	5	0.60
MALI	12144	838	6.9	5	0	0.0	0	100.0	0	0.00
MAURITANIA	554	29	5.2	5	0	0.0	0	100.0	0	0.10
NIGER	2550	99	3.9	12	0	0.0	0	0.0	0	0.00
SENEGAL	7544	453	6.0	20	0	5.0	0	95.0	0	0.00
WEST SAHELIAN AFRICA	**40761**	**2935**	**7.2**	**9**	**5**	**77.9**	**1**	**22.1**	**6**	**0.20**
ETHIOPIA	14165	5226	36.9	30	0	92.2	0	7.8	0	0.00
KENYA	1187	408	34.4	27	2	85.9	0	14.1	2	0.60
SOMALIA	754	123	16.3	12	0	0.0	1	100.0	1	0.60
SUDAN	42976	1482	3.4	18	0	0.0	0	100.0	0	0.00
UGANDA	6346	806	12.7	27	0	60.5	0	39.5	1	0.10
EAST SAHELIAN AFRICA	**65428**	**8044**	**12.3**	**23**	**3**	**65.4**	**1**	**34.6**	**4**	**0.10**
BENIN	4947	50	1.0	4	0	56.8	0	43.2	0	0.30
CTE D'IVOIRE	10904	1123	10.3	25	29	34.0	56	66.0	85	7.60
GHANA	9555	1596	16.7	24	2	19.2	9	80.8	11	0.70
GUINEA	6692	1626	24.3	7	8	87.0	1	13.0	9	0.50
LIBERIA	4633	4633	100.0	8	68	87.1	10	12.9	79	1.70
NIGERIA	15634	5613	35.9	35	39	30.5	88	69.5	127	2.30
SIERRA LEONE	1889	680	36.0	13	0	0.0	1	100.0	1	0.20
TOGO	1353	248	18.3	10	0	47.4	0	52.6	1	0.30
WEST AFRICA	**55607**	**15568**	**28.0**	**16**	**146**	**46.9**	**166**	**53.1**	**312**	**2.00**
CAMEROON	20350	7428	36.5	6	297	89.3	36	10.7	333	4.50
CENTRAL AFRICAN REP.	30562	7824	25.6	15	3	93.3	0	6.7	3	0.00
CONGO	19865	19527	98.3	8	70	88.9	9	11.1	78	0.40
EQUATORIAL GUINEA	1826	1826	100.0	25	5	87.9	1	12.1	5	0.30
GABON	18235	18162	99.6	10	117	92.8	9	7.2	126	0.70
ZAIRE	113275	103533	91.4	15	24	95.3	1	4.7	26	0.00
CENTRAL AFRICA	**204112**	**158300**	**77.6**	**13**	**516**	**90.3**	**56**	**9.7**	**571**	**0.40**
ANGOLA	23074	2307	10.0	15	0	4.8	1	95.2	1	0.00
BURUNDI	233	54	23.1	30	0	0.0	0	0.0	0	0.00
MALAWI	3486	1154	33.1	15	0	0.0	0	100.0	0	0.00
MOZAMBIQUE	17329	4402	25.4	10	0	40.4	1	59.6	1	0.00
RWANDA	164	137	83.8	30	0	4.9	1	95.1	1	0.40
TANZANIA	33555	1141	3.4	5	1	76.6	0	23.4	2	0.20
ZAMBIA	32301	3295	10.2	5	2	33.8	3	66.2	5	0.20
ZIMBABWE	8897	71	0.8	12	0	13.9	0	86.1	0	0.20
TROPICAL S. AFRICA	**119038**	**12561**	**10.6**	**15**	**4**	**38.1**	**6**	**61.9**	**9**	**0.10**
MADAGASCAR	15782	7196	45.6	24	6	30.6	14	69.4	20	0.30
INSULAR AFRICA	**15782**	**7196**	**45.6**	**24**	**6**	**30.6**	**14**	**69.4**	**20**	**0.30**
TOTAL	**500727**	**204603**	**40.9**	**15**	**679**	**73.6**	**243**	**26.4**	**922**	**0.50**

Table 5b: state of logging 1990

REGION: ASIA **YEAR: 1990**

Country	Forest area			Closed broadleaved forest						
	Total	Closed broadleaved forest		Average logging intensity	Annually logged area 1981-90					
					Newly logged		Previously logged		Total logged area	
	000 ha	000 ha	%	m³/ha	000 ha	%	000 ha	%	000 ha	% of total closed broadleaved forest area
BANGLADESH	769	592	77.0	30	1	7.1	14	92.9	15	2.50
BHUTAN	2809	1141	40.6	76	2	78.9	1	21.1	2	0.20
INDIA	51729	28747	55.6	20	8	18.2	35	81.8	42	0.10
SRI LANKA	1746	1374	78.7	45	0	3.3	3	96.7	3	0.20
SOUTH ASIA	**57053**	**31854**	**55.8**	**43**	**11**	**17.0**	**52**	**83.0**	**62**	**0.20**
CAMBODIA	12163	6209	51.0	20	3	87.8	0	12.2	3	0.00
LAOS	13173	10418	79.1	12	8	93.7	1	6.3	9	0.10
MYANMAR	28856	28741	99.6	14	178	90.0	20	10.0	198	0.70
THAILAND	12735	8216	64.5	24	17	45.0	20	55.0	37	0.50
VIETNAM	8312	4946	59.5	30	26	45.3	32	54.7	58	1.20
CONTINENT. S.E. ASIA	**75240**	**58529**	**77.8**	**20**	**232**	**76.1**	**73**	**23.9**	**304**	**0.50**
BRUNEI	458	458	100.0	75	3	93.4	0	6.6	3	0.60
INDONESIA	109549	86393	78.9	20	1054	86.2	169	13.8	1223	1.40
MALAYSIA	17583	17583	100.0	75	385	84.7	70	15.3	455	2.60
PHILIPPINES	7831	7606	97.1	83	25	61.8	16	38.2	41	0.50
INSULAR S. E. ASIA	**135422**	**112040**	**82.7**	**63**	**1467**	**85.2**	**254**	**14.8**	**1721**	**1.50**
PAPUA NEW GUINEA	36000	31808	88.4	32	53	93.3	4	6.7	57	0.20
PACIFIC	**36000**	**31808**	**88.4**	**32**	**53**	**93.3**	**4**	**6.7**	**57**	**0.20**
TOTAL	**303714**	**234231**	**77.1**	**40**	**1762**	**82.2**	**382**	**17.8**	**2144**	**0.90**

Table 5c: state of logging 1990

REGION: LATIN AMERICA AND THE CARIBBEAN **YEAR: 1990**

Country	Forest area			Closed broadleaved forest						
	Total	Closed broadleaved forest		Average logging intensity	Annually logged area 1981-1990					
					Newly logged		Previously logged		Total logged area	
									000 ha	% of total closed broadleaved forest area
	000 ha	000 ha	%	m^3/ha	000 ha	%	000 ha	%		
COSTA RICA	1428	1301	91.1	22	9	27.1	25	72.9	34	2.60
GUATEMALA	4225	3946	93.4	10	1	50.2	1	49.8	3	0.10
HONDURAS	4605	2406	52.2	10	0	18.9	1	81.1	2	0.10
MEXICO	48586	8177	16.8	15	4	93.5	0	6.5	4	0.00
NICARAGUA	6013	4738	78.8	10	42	92.4	3	7.6	45	0.90
PANAMA	3117	3117	100.0	30	2	71.2	1	28.8	3	0.10
CENTRAL AMERICA	**67973**	**23685**	**34.8**	**16**	**58**	**64.6**	**32**	**35.4**	**90**	**0.40**
BELIZE	1996	1868	93.6	10	0	5.0	3	95.0	3	0.20
CUBA	1715	1715	100.0	15	0	8.4	2	91.6	3	0.20
DOMINICAN REP.	1077	854	79.3	10	0	61.3	0	38.7	0	0.00
FRENCH GUYANA	7997	7925	99.1	16	11	95.0	1	5.0	11	0.10
GUADELOUPE	93	93	100.0	10	0	61.1	0	38.9	0	0.20
GUYANA	18416	18195	98.8	20	8	91.2	1	8.8	9	0.00
HAITI	23	18	75.1	15	0	11.3	1	88.7	1	7.70
JAMAICA	239	239	100.0	14	1	90.6	0	9.4	1	0.30
MARTINIQUE	43	43	100.0	10	0	60.5	0	39.5	0	0.30
SURINAME	14768	14605	98.9	16	10	93.6	1	6.4	11	0.10
TRINIDAD & TOBAGO	155	155	100.0	15	0	4.3	3	95.7	3	1.80
CARIBBEAN	**46521**	**45709**	**98.3**	**14**	**31**	**72.5**	**12**	**27.5**	**42**	**0.10**
BOLIVIA	49317	40785	82.7	13	9	71.3	3	28.7	12	0.00
BRAZIL	561107	387121	69.0	6	1842	93.0	140	7.0	1982	0.50
COLOMBIA	54064	49793	92.1	16	101	93.6	7	6.4	108	0.20
ECUADOR	11962	11771	98.4	15	145	95.9	6	4.1	152	1.30
PARAGUAY	12859	2649	20.6	11	9	19.2	39	80.8	49	1.80
PERU	67906	66282	97.6	12	76	84.7	14	15.3	89	0.10
VENEZUELA	45690	40573	88.8	11	21	39.2	33	60.8	54	0.10
TROPICAL S. AMERICA	**802904**	**598974**	**74.6**	**12**	**2203**	**90.1**	**242**	**9.9**	**2445**	**0.40**
TOTAL	**917398**	**668367**	**72.9**	**14**	**2292**	**88.9**	**286**	**11.1**	**2577**	**0.40**
GRAND TOTAL	**1721839**	**1107201**	**64.3**	**19**	**4732**	**83.9**	**911**	**16.1**	**5643**	**0.50**

Notes:
- numbers may not tally due to rounding
- ε indicates a very small value

Table 6a: Land area and forest cover by ecological zone

REGION: AFRICA **YEAR: 1990**

Country	Ecological zone											
	Wet zone		Moist zone		Dry zone		Very dry zone		Desert zone (cold/hot)		Hill and mountain zone	
	Land area	Forest cover	Land area	Forest cover	Land area	Forest cover	Land area	Forest cover	Land area	For. cov.	Land area	For. cov.
	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000 ha	%
BURKINA FASO	0	0	7956	27	12164	13	7259	11	0	0	0	0
CAPE VERDE	0	0	0	0	0	0	403	2	0	0	0	0
CHAD	0	0	12511	31	15731	32	33731	7	61490	ε	2456	0
GAMBIA	0	0	762	10	238	7	0	0	0	0	0	0
GUINEA-BUISSAU	0	0	2812	72	0	0	0	0	0	0	0	0
MALI	0	0	11207	33	9433	48	40283	10	61096	0	0	0
MAURITANIA	0	0	0	0	0	0	25165	2	77357	0	0	0
NIGER	0	0	0	0	1094	17	48652	5	76924	0	0	0
SENEGAL	0	0	4591	56	3941	44	10721	30	0	0	0	0
W. SAHELIAN AFRICA	**0**	**0**	**39840**	**36**	**42601**	**31**	**166214**	**8**	**276867**	**0**	**2456**	**0**
DJIBOUTI	0	0	0	0	0	0	0	0	2318	1	0	0
ETHIOPIA	0	0	0	0	8764	23	30393	18	24448	3	46494	13
KENYA	0	0	752	2	1102	2	42771	ε	247	37	12096	8
SOMALIA	0	0	0	0	0	0	33122	2	28552	0	1060	0
SUDAN	0	0	18440	68	42974	41	81856	15	92456	0	1874	38
UGANDA	0	0	2903	38	0	0	1365	17	67	67	15620	32
EAST SAHELIAN AFRICA	**0**	**0**	**22095**	**61**	**52840**	**37**	**189507**	**10**	**148089**	**1**	**77146**	**17**
BENIN	0	0	9457	44	1605	48	0	0	0	0	0	0
COTE D'IVOIRE	0	0	31700	34	0	0	0	0	0	0	100	73
GHANA	0	0	22161	41	841	48	0	0	0	0	0	0
GUINEA	1189	32	22387	28	0	0	0	0	0	0	1010	13
LIBERIA	2686	33	6989	54	0	0	0	0	0	0	1	21
NIGERIA	2203	54	54559	22	18637	7	13984	6	0	0	1693	14
SIERRA LEONE	3139	24	3964	28	0	0	0	0	0	0	59	42
TOGO	0	0	4187	31	429	8	823	0	0	0	0	0
WEST AFRICA	**9216**	**35**	**155405**	**31**	**21512**	**12**	**14808**	**5**	**0**	**0**	**2862**	**16**
CAMEROON	12334	65	23682	42	3380	17	865	10	0	0	6279	28
CENTRAL AFRICAN REP.	616	100	54579	52	5830	14	0	0	0	0	1273	61
CONGO	8020	96	26130	47	0	0	0	0	0	0	0	0
EQUATORIAL GUINEA	1378	64	1379	67	0	0	0	0	0	0	48	30
GABON	1667	69	24100	71	0	0	0	0	0	0	0	0
ZAIRE	79761	76	125089	36	543	20	0	0	ε	53	21366	35
CENTRAL AFRICA	**103776**	**76**	**254959**	**45**	**9752**	**16**	**865**	**10**	**0**	**0**	**28967**	**35**
ANGOLA	0	0	60801	20	37204	19	6181	12	3936	0	16547	19
BOTSWANA	0	0	0	0	10572	28	45174	24	927	54	0	0
BURUNDI	0	0	334	14	0	0	0	0	0	0	2231	8
MALAWI	0	0	7918	37	634	26	0	0	0	0	856	44
MOZAMBIQUE	0	0	25493	26	49052	21	3688	17	0	0	177	7
NAMIBIA	0	0	0	0	11356	22	35618	22	35354	6	0	0
RWANDA	0	0	0	0	0	0	0	0	0	0	2467	7
TANZANIA	0	0	32247	44	32223	38	11584	35	117	11	12432	24
ZAMBIA	0	0	49636	44	23933	43	0	0	0	0	770	44
ZIMBABWE	0	0	0	0	33343	23	4903	22	0	0	4217	16
TROPICAL S. AFRICA	**0**	**0**	**176429**	**32**	**198316**	**27**	**107148**	**24**	**40336**	**6**	**35902**	**20**
MADAGASCAR	8228	55	17260	22	9355	24	4187	16	0	0	19124	24
INSULAR AFRICA	**8228**	**55**	**17260**	**22**	**9355**	**24**	**4187**	**16**	**0**	**0**	**19124**	**24**
TOTAL	**121221**	**71**	**665988**	**38**	**334377**	**28**	**482729**	**12**	**465291**	**1**	**166457**	**21**

Table 6b: Land area and forest cover by ecological zone

REGION: ASIA AND THE PACIFIC **YEAR:** 1990

Country	Ecological zone											
	Wet zone		Moist zone		Dry zone		Very dry zone		Desert zone (cold/hot)		Hill and Montane zone	
	Land area	Forest cover	Land area	Forest cover	Land area	Forest cover	Land area	Forest cover	Land area	For. cover	Land area	For. cover
	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000 ha	%
BANGLADESH	4606	12	8410	2	0	0	0	0	0	0	0	0
BHUTAN	352	50	0	0	0	0	0	0	1299	31	3049	73
INDIA	18425	45	40474	17	178002	15	18519	0	24317	5	17603	51
NEPAL	1847	33	3010	43	165	22	0	0	3811	19	4847	49
PAKISTAN	0	0	255	4	4784	0	21633	0	27557	1	22859	6
SRI LANKA	1810	14	2331	26	2088	40	0	0	0	0	234	24
SOUTH ASIA	**27041**	**36**	**54480**	**17**	**185039**	**15**	**40152**	**0**	**56985**	**5**	**48592**	**31**
CAMBODIA	1965	86	4999	72	10594	64	0	0	0	0	95	98
LAOS	5594	71	7523	60	3638	62	0	0	0	0	6325	38
MYANMAR	22130	55	22087	47	5969	6	0	0	248	17	15363	39
THAILAND	13051	24	11733	45	24065	13	0	0	0	0	2240	56
VIETNAM	6981	41	16365	21	4485	21	0	0	0	0	4717	23
CONTINENTAL S.E. ASIA	**49720**	**48**	**62708**	**43**	**48751**	**28**	**0**	**0**	**248**	**17**	**28740**	**38**
BRUNEI	527	87	0	0	0	0	0	0	0	0	0	0
INDONESIA	147515	64	16007	21	1348	5	0	0	106	73	16182	75
MALAYSIA	31189	52	0	0	0	0	0	0	0	0	1666	86
PHILIPPINES	17069	22	10728	19	0	0	0	0	0	0	2020	100
SINGAPORE	61	7	0	0	0	0	0	0	0	0	0	0
INSULAR S.E. ASIA	**196360**	**58**	**26735**	**20**	**1348**	**5**	**0**	**0**	**106**	**73**	**19869**	**81**
PAPUA NEW GUINEA	34261	86	2601	27	1242	34	0	0	330	56	6853	78
PACIFIC	**34261**	**86**	**2601**	**27**	**1242**	**34**	**0**	**0**	**330**	**56**	**6853**	**78**
TOTAL	**307361**	**58**	**146523**	**29**	**236379**	**17**	**40152**	**0**	**57668**	**5**	**104054**	**48**

Table 6c. Land area and forest cover by ecological zone

REGION: LATIN AMERICA AND THE CARIBBEAN **YEAR:** 1990

Country	Ecological zone											
	Wet zone		Moist zone		Dry zone		Very dry zone		Desert zone (cold/hot)		Hill and montane zone	
	Land area	Forest cover	Land area	Forest cover	Land area	Forest cover	Land area	Forest cover	Land area	Forest cover	Land area	Forest cover
	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000 ha	%
COSTA RICA	2236	28	0	25	0	0	0	0	0	0	2870	28
EL SALVADOR	551	6	206	6	0	0	0	0	0	0	1328	6
GUATEMALA	3795	67	731	100	0	0	0	0	0	0	6318	15
HONDURAS	3125	41	1061	41	0	0	0	0	0	0	7003	41
MEXICO	3484	70	32398	34	7776	20	4151	18	15161	9	127900	24
NICARAGUA	7331	51	687	51	0	0	0	0	0	0	3857	51
PANAMA	4336	42	495	13	0	0	0	0	0	0	2768	45
CENTRAL AMERICA	**24857**	**50**	**35577**	**38**	**7776**	**20**	**4151**	**18**	**15161**	**9**	**152045**	**25**
ANTIGUA\BARBUDA	0	0	44	22	0	0	0	0	0	0	0	0
BAHAMAS	0	0	668	19	255	19	24	21	19	21	34	19
BELIZE	1741	100	238	100	0	0	0	0	0	0	300	6
CUBA	729	16	7985	16	15	16	0	0	0	0	2254	16
DOMINICA	75	59	0	0	0	0	0	0	0	0	0	0
DOMINICAN REP.	1531	22	1228	22	0	0	0	0	0	0	2080	22
FRENCH GUYANA	8774	91	41	7	0	0	0	0	0	0	0	0
GRENADA	0	0	34	16	0	0	0	0	0	0	0	0
GUADELOUPE	169	55	0	0	0	0	0	0	0	0	0	0
GUYANA	11671	100	6346	76	0	0	0	0	0	0	1668	100
HAITI	534	1	1039	1	2	1	0	0	0	0	1181	1
JAMAICA	554	22	514	22	0	22	0	0	0	0	15	22
MARTINIQUE	106	40	0	0	0	0	0	0	0	0	0	38
PUERTO RICO	136	36	416	36	0	0	0	0	0	0	333	36
ST. KITTS\NEVIS	0	0	36	37	0	0	0	0	0	0	0	0
ST. LUCIA	61	7	0	0	0	0	0	0	0	0	0	0
ST. VINCENT	38	27	1	27	0	0	0	0	0	0	0	0
SURINAME	9042	100	6558	87	0	0	0	0	0	0	0	0
TRINIDAD\TOBAGO	513	30	0	0	0	0	0	0	0	0	0	0
CARIBBEAN	**35674**	**88**	**25148**	**52**	**272**	**18**	**24**	**19**	**19**	**4**	**7865**	**36**
BOLIVIA	0	0	55167	64	15958	46	0	0	23076	0	14236	45
BRAZIL	313340	93	259380	76	83755	34	0	0	0	0	189176	23
COLOMBIA	55859	85	25529	16	1561	1	940	0	771	0	19211	13
ECUADOR	10590	68	3951	42	1000	4	203	0	3545	0	8395	37
PARAGUAY	0	0	21247	28	18021	38	0	0	0	0	462	6
PERU	47055	86	13232	93	388	5	7127	4	22896	1	37302	40
VENEZUELA	21176	93	46815	33	4882	5	1348	1	126	0	13857	75
TROP. S. AMERICA	**448020**	**91**	**425320**	**64**	**125565**	**34**	**9618**	**3**	**50415**	**0**	**282639**	**29**
TOTAL	**508552**	**88**	**486046**	**61**	**133613**	**34**	**13793**	**8**	**65594**	**2**	**442549**	**28**
GRAND TOTAL	**937134**	**77**	**1298557**	**45**	**704369**	**25**	**536674**	**11.2**	**588553**	**1**	**713060**	**29**

Notes: - numbers may not tally due to rounding
- ε indicates a very small value

The estimates of forest cover area and changes by forest formation are derived by integrating FORIS database with ecofloristic zone and vegetation maps, computerised at 1:5 million scale, for use at subregional, regional and global levels. This fact may be kept in view while making use of country level areas.

Table 7a: Area of forest formations

REGION: AFRICA **YEAR: 1990**

Country	Forest formation												
	Total forest	Tropical rain forest		Moist deciduous forest		Dry deciduous forest		Very dry forest		Desert cold/hot		Hill and mountains	
	000 ha	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000ha	%	000 ha	%
BURKINA FASO	4416	0	0	2112	48	1533	35	771	17	0	0	0	0
CAPE VERDE	6	0	0	0	0	0	0	6	100	0	0	0	0
CHAD	11434	0	0	3932	34	5024	44	2461	22	17	ε	0	0
GAMBIA	97	0	0	79	82	18	18	0	0	0	0	0	0
GUINEA-BUISSAU	2021	0	0	2021	100	0	0	0	0	0	0	0	0
MALI	12144	0	0	3706	31	4548	37	3891	32	0	0	0	0
MAURITANIA	554	0	0	0	0	0	0	554	100	0	0	0	0
NIGER	2550	0	0	0	0	190	7	2359	93	0	0	0	0
SENEGAL	7544	0	0	2586	34	1716	23	3242	43	0	0	0	0
WEST SAHELIAN AFRICA	**40767**	**0**	**0**	**14437**	**35**	**13029**	**32**	**13285**	**33**	**17**	**0**	**0**	**0**
DJIBOUTI	22	0	0	0	0	0	0	0	0	22	100	0	0
ETHIOPIA	14165	0	0	0	0	2008	14	5346	38	639	5	6173	44
KENYA	1187	0	0	13	1	19	2	156	13	91	8	908	77
SOMALIA	754	0	0	0	0	0	0	754	100	0	0	0	0
SUDAN	42976	0	0	12472	29	17757	41	12027	28	0	0	720	2
UGANDA	6346	0	0	1091	17	0	0	231	4	45	1	4980	78
EAST SAHELIAN AFRICA	**65450**	**0**	**0**	**13576**	**21**	**19784**	**30**	**18513**	**28**	**797**	**1**	**12780**	**20**
BENIN	4947	0	0	4183	85	764	15	0	0	0	0	0	0
COTE D'IVOIRE	10904	0	0	10831	99	0	0	0	0	0	0	73	1
GHANA	9555	0	0	9151	96	404	4	0	0	0	0	0	0
GUINEA	6692	385	6	6180	92	0	0	0	0	0	0	128	2
LIBERIA	4633	893	19	3741	81	0	0	0	0	0	0	ε	ε
NIGERIA	15634	1197	8	12011	77	1380	9	803	5	0	0	243	2
SIERRA LEONE	1889	756	40	1108	59	0	0	0	0	0	0	25	0
TOGO	1353	0	0	1318	98	35	3	0	0	0	0	0	0
WEST AFRICA	**55607**	**3230**	**6**	**48523**	**87**	**2583**	**5**	**803**	**1**	**0**	**0**	**468**	**1**
CAMEROON	20350	8021	39	9892	49	585	3	86	ε	0	0	1767	9
CENTRAL AFRICAN REP.	30562	719	1	28255	93	816	3	0	0	0	0	772	3
CONGO	19865	7667	39	12198	61	0	0	0	0	0	0	0	0
EQUATORIAL GUINEA	1826	822	48	930	51	0	0	0	0	0	0	14	1
GABON	18235	1155	6	17080	94	0	0	0	0	0	0	0	0
ZAÏRE	113275	60437	53	45209	40	111	ε	0	0	ε	ε	7518	7
CENTRAL AFRICA	**204112**	**78880**	**39**	**113563**	**56**	**1512**	**1**	**86**	**0**	**0**	**0**	**10072**	**5**
ANGOLA	23074	0	0	11942	52	7218	31	751	3	0	0	3163	14
BOTSWANA	14261	0	0	0	0	2940	21	10816	76	504	4	0	0
BURUNDI	233	0	0	47	20	0	0	0	0	0	0	186	80
MALAWI	3486	0	0	2948	85	166	5	0	0	0	0	373	11
MOZAMBIQUE	17329	0	0	6526	38	10163	59	627	4	0	0	13	ε
NAMIBIA	12569	0	0	0	0	2521	20	7994	64	2054	16	0	0
RWANDA	164	0	0	0	0	0	0	0	0	0	0	164	100
TANZANIA	33555	0	0	14128	42	12375	37	4004	12	13	ε	3035	9
ZAMBIA	32301	0	0	21676	67	10288	32	0	0	0	0	337	1
ZIMBABWE	8897	0	0	0	0	7729	87	1099	12	0	0	69	1
TROPICAL S. AFRICA	**145868**	**0**	**0**	**57267**	**39**	**53400**	**37**	**25291**	**17**	**2571**	**2**	**7339**	**5**
MADAGASCAR	15782	4507	29	3777	24	2219	14	682	4	0	0	4596	29
INSULAR AFRICA	**15782**	**4507**	**29**	**3777**	**24**	**2219**	**14**	**682**	**4**	**0**	**0**	**4596**	**29**
TOTAL	**527586**	**86616**	**16**	**251143**	**48**	**92527**	**18**	**58660**	**11**	**3385**	**1**	**35256**	**7**

Table 7b: Area of forest formations

REGION: ASIA AND THE PACIFIC **YEAR:** 1990

Country	Forest formation												
	Total forest	Tropical rain forest		Moist deciduous forest		Dry deciduous forest		Very dry forest		Desert (cold/hot)		Hill and Montane	
	000 ha	000 ha	%	000 ha	%	000 ha	%	000ha	%	000ha	%	000 ha	%
BANGLADESH	769	572	74	197	26	0	0	0	0	0	0	0	0
BHUTAN	2809	176	6	0	0	0	0	0	0	403	14	2230	79
INDIA	51729	8246	16	7042	14	26242	51	0	0	1283	2	8917	17
NEPAL	5023	609	12	1300	26	37	1	0	0	716	14	2361	47
PAKISTAN	1855	0	0	11	1	4	0	37	2	380	20	1423	77
SRI LANKA	1746	247	14	605	35	836	48	0	0	0	0	57	3
SOUTH ASIA	**63931**	**9850**	**15**	**9155**	**14**	**27119**	**42**	**37**	**0**	**2781**	**5**	**14989**	**24**
CAMBODIA	12163	1689	14	3610	30	6771	56	0	0	0	0	93	1
LAOS	13173	3960	30	4542	34	2267	17	0	0	0	0	2405	18
MYANMAR	28856	12094	42	10427	36	351	1	0	0	43	0	5942	21
THAILAND	12735	3082	24	5232	41	3159	25	0	0	0	0	1263	10
VIETNAM	8312	2894	35	3382	41	952	11	0	0	0	0	1084	13
CONTINENTAL S.E. ASIA	**75240**	**23719**	**32**	**27192**	**36**	**13499**	**18**	**0**	**0**	**43**	**0**	**10786**	**14**
BRUNEI	458	458	100	0	0	0	0	0	0	0	0	0	0
INDONESIA	109549	93950	86	3366	3	73	0	0	0	77	0	12083	11
MALAYSIA	17583	16339	93	0	0	0	0	0	0	0	0	1244	7
PHILIPPINES	7831	3728	48	1413	18	0	0	0	0	0	0	2690	34
SINGAPORE	4	4	100	0	0	0	0	0	0	0	0	0	0
INSULAR S.E. ASIA	**135426**	**114479**	**85**	**4779**	**4**	**73**	**0**	**0**	**0**	**77**	**0**	**16018**	**12**
PAPUA NEW GUINEA	36000	29323	81	705	2	417	1	0	0	184	1	5370	15
PACIFIC	**36000**	**29323**	**81**	**705**	**2**	**417**	**1**	**0**	**0**	**184**	**1**	**5370**	**15**
TOTAL	**310597**	**177371**	**57**	**41832**	**13**	**41108**	**13**	**37**	**0**	**3085**	**1**	**47163**	**15**

Table 7c: Area of forest formations

REGION: LATIN AMERICA AND THE CARIBBEAN **YEAR**: 1990

COUNTRY	**Forest formation**												
	Total forest	**Tropical rain forest zone**		**Moist deciduous forest zone**		**Dry deciduous forest zone**		**Very dry forest zone**		**Desert zone (cold/hot)**		**Hill and montane zone**	
	000 ha	**000 ha**	**%**	**000 ha**	**%**	**000 ha**	**%**	**000 ha**	**%**	**000 ha**	**%**	**000 ha**	**%**
COSTA RICA	1428	625	44	0	0	0	0	0	0	0	0	802	56
EL SALVADOR	123	33	26	12	10	0	0	0	0	0	0	79	64
GUATEMALA	4225	2542	60	1615	38	0	0	0	0	0	0	69	2
HONDURAS	4605	1286	28	437	9	0	0	0	0	0	0	2882	63
MEXICO	48586	2441	5	11110	23	1590	3	759	2	1424	3	31261	64
NICARAGUA	6013	3712	62	348	6	0	0	0	0	0	0	1953	32
PANAMA	3117	1802	58	67	2	0	0	0	0	0	0	1249	40
CENTRAL AMERICA	**68097**	**12440**	**16**	**13588**	**18**	**1590**	**3**	**759**	**2**	**1424**	**3**	**38294**	**53**
ANTIGUA\BARBUDA	10	0	0	10	100	0	0	0	0	0	0	0	0
BAHAMAS	186	0	0	124	67	47	25	5	2	4	2	6	3
BELIZE	1996	1957	98	39	2	0	0	0	0	0	0	16	1
CUBA	1715	114	7	1247	73	2	0	0	0	0	0	352	21
DOMINICA	44	44	100	0	0	0	0	0	0	0	0	0	0
DOMINICAN REP.	1077	341	32	273	25	0	0	0	0	0	0	463	43
FRENCH GUYANA	7997	7993	100	3	0	0	0	0	0	0	0	0	0
GRENADA	6	0	0	6	100	0	0	0	0	0	0	0	0
GUADELOUPE	93	93	100	0	0	0	0	0	0	0	0	0	0
GUYANA	18416	13337	72	3167	17	0	0	0	0	0	0	1912	10
HAITI	23	5	19	9	38	0	0	0	0	0	0	10	43
JAMAICA	239	122	51	113	47	0	0	0	0	0	0	3	1
MARTINIQUE	43	43	100	0	0	0	0	0	0	0	0	0	0
PUERTO RICO	321	49	15	151	47	0	0	0	0	0	0	121	38
ST. KITTS\NEVIS	13	0	0	13	100	0	0	0	0	0	0	0	0
ST. LUCIA	5	5	100	0	0	0	0	0	0	0	0	0	0
ST. VINCENT	11	10	98	0	2	0	0	0	0	0	0	0	0
SURINAME	14768	11440	77	3328	23	0	0	0	0	0	0	0	0
TRINIDAD\TOBAGO	155	155	100	0	0	0	0	0	0	0	0	0	0
CARIBBEAN	**47115**	**35707**	**76**	**8483**	**18**	**49**	**25**	**5**	**2**	**4**	**2**	**2867**	**6**
BOLIVIA	49317	0	0	35582	72	7346	15	0	0	4	0	6385	13
BRAZIL	561107	291597	52	197082	35	28863	5	0	0	0	0	43565	8
COLOMBIA	54064	47455	88	4101	8	18	0	0	0	0	0	2490	5
ECUADOR	11962	7150	60	1669	14	44	0	0	0	0	0	3100	26
PARAGUAY	12859	0	0	6037	47	6794	53	0	0	0	0	27	0
PERU	67906	40358	59	12299	18	19	0	269	0	184	0	14777	22
VENEZUELA	45691	19602	43	15465	34	222	0	12	0	0	0	10390	23
S. AMERICA	**802904**	**406162**	**51**	**272235**	**34**	**43304**	**5**	**282**	**0**	**188**	**0**	**80734**	**10**
TOTAL	**918116**	**454309**	**49**	**294306**	**32**	**44944**	**5**	**1045**	**0**	**1616**	**0**	**121895**	**13**
GRAND TOTAL	**1 756 299**	**718 297**	**41**	**587 281**	**34**	**178 579**	**10**	**59 742**	**3**	**8 086**	**1**	**204 314**	**12**

Notes:
- numbers may not tally due to rounding
- ε indicates a very small value

The estimates of forest cover area and changes by forest formation are derived by integrating FORIS database with ecofloristic zone and vegetation maps, computerised at 1:5 million scale, for use at subregional, regional and global levels. This fact may be kept in view while making use of country level areas.

Table 8a: Annual deforestation during 1981-90 by forest formations

REGION: AFRICA **YEAR: 1990**

Country	Annual deforestation 1981-90												
	Total	Tropical rain forest zone		Moist deciduous forest zone		Dry deciduous forest zone		Very dry forest zone		Desert zone (cold/hot)		Hill and montane zone	
	000 ha	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000ha	%	000 ha	%
BURKINA FASO	31.9	0.0	0.0	15.3	47.8	11.1	34.7	5.6	17.5	0.0	0.0	0.0	0.0
CAPE VERDE	ε	0.0	0.0	0.0	0.0	0.0	0.0	ε	100.0	0.0	0.0	0.0	0.0
CHAD	88.5	0.0	0.0	48.2	54.4	26.1	29.5	14.2	16.1	0.0	0.0	0.0	0.0
GAMBIA	0.8	0.0	0.0	0.6	81.8	0.1	18.1	0	0.0	0.0	0.0	0.0	0.0
GUINEA-BISSAU	15.9	0.0	0.0	15.9	100.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
MALI	106.3	0.0	0.0	37.7	35.5	40.7	38.3	27.9	26.2	0.0	0.0	0.0	0.0
MAURITANIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NIGER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SENEGAL	51.8	0.0	0.0	18.1	34.9	13.0	25.0	20.8	40.1	0.0	0.0	0.0	0.0
WEST SAHELIAN AFRICA	**295.2**	**0.0**	**0.0**	**135.8**	**46.0**	**91.0**	**30.8**	**68.5**	**23.2**	**0.0**	**0.0**	**0.0**	**0.0**
DJIBOUTI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ETHIOPIA	38.6	0.0	0.0	0.0	0.0	5.8	15.1	12.7	32.9	1.1	2.9	19.0	49.1
KENYA	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.0	0.9	13.6	5.7	82.5
SOMALIA	2.8	0.0	0.0	0.0	0.0	0.0	0.0	2.8	100.0	0.0	0.0	0.0	0.0
SUDAN	481.7	0.0	0.0	213.3	44.3	175.7	36.5	81.0	16.8	0.0	0.0	11.7	2.4
UGANDA	64.5	0.0	0.0	13.8	21.4	0.0	0.0	1.6	2.6	0.6	1.0	48.4	75.1
EAST SAHELIAN AFRICA	**594.5**	**0.0**	**0.0**	**227.1**	**38.2**	**181.6**	**30.5**	**98.4**	**16.6**	**2.7**	**0.0**	**84.8**	**14.3**
BENIN	69.7	0.0	0.0	56.7	81.4	13.0	18.6	0.0	0.0	0.0	0.0	0.0	0.0
COTE D'IVOIRE	119.4	0.0	0.0	118.9	99.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4
GHANA	137.5	0.0	0.0	134.0	97.5	3.4	2.5	0.0	0.0	0.0	0.0	0.0	0.0
GUINEA	86.6	0.4	0.4	84.4	97.5	0.0	0.0	0.0	0.0	0.0	0.0	1.8	2.1
LIBERIA	25.4	5.5	21.9	19.8	78.2	0.0	0.0	0.0	0.0	0.0	0.0	ε	ε
NIGERIA	118.7	7.2	6.1	101.0	85.0	6.5	5.4	1.6	1.4	0.0	0.0	2.4	2.0
SIERRA LEONE	12.3	4.9	40.0	7.2	58.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3
TOGO	21.8	0.0	0.0	21.6	98.9	0.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0
WEST AFRICA	**591.3**	**18.1**	**0.0**	**543.7**	**91.9**	**23.1**	**7.8**	**1.6**	**0.3**	**0.0**	**0.0**	**4.9**	**1.7**
CAMEROON	122.0	36.5	30.0	66.9	54.9	5.3	4.4	0.2	0.1	0.0	0.0	13.0	10.7
CENTRAL AFRICAN REP.	129.3	4.5	3.5	118.7	91.8	2.8	2.2	0.0	0.0	0.0	0.0	3.3	2.6
CONGO	32.3	12.8	39.6	19.5	60.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EQUATORIAL GUINEA	7.0	3.3	47.9	3.6	51.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9
GABON	116.4	7.4	6.3	109.0	93.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZAÏRE	732.2	361.1	49.3	300.7	41.1	0.7	0.1	0.0	0.0	ε	ε	69.7	9.5
CENTRAL AFRICA	**1139.8**	**425.6**	**37.3**	**618.7**	**54.3**	**8.8**	**0.8**	**0.2**	**0.0**	**0.0**	**0.0**	**86.1**	**7.6**
ANGOLA	173.8	0.0	0.0	89.9	51.8	54.4	31.3	5.7	3.3	0.0	0.0	23.8	13.7
BOTSWANA	76.9	0.0	0.0	0.0	0.0	15.8	20.6	58.3	75.9	2.7	3.5	0.0	0.0
BURUNDI	1.4	0.0	0.0	0.4	25.6	0.0	0.0	0.0	0.0	0.0	0.0	1.0	74.5
MALAWI	52.5	0.0	0.0	45.0	85.8	2.5	4.9	0.0	0.0	0.0	0.0	4.9	9.4
MOZAMBIQUE	135.3	0.0	0.0	62.0	45.8	71.8	53.1	1.4	1.0	0.0	0.0	0.1	0.1
NAMIBIA	43.1	0.0	0.0	0.0	0	8.6	20.0	27.4	63.5	7.0	16.3	0.0	0.0
RWANDA	0.4	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	100.0
TANZANIA	438.2	0.0	0.0	227.8	52.0	130.3	29.7	41.2	9.4	0.1	ε	38.8	8.9
ZAMBIA	362.9	0.0	0.0	254.5	70.1	106.0	29.2	0.0	0.0	0.0	0.0	2.4	0.7
ZIMBABWE	60.9	0.0	0.0	0.0	0	52.9	86.9	7.5	12.4	0.0	0.0	0.5	0.8
TROPICAL S. AFRICA	**1345.4**	**0.0**	**0.0**	**679.7**	**50.5**	**442.5**	**32.9**	**141.4**	**10.5**	**9.9**	**0.8**	**72.0**	**5.3**
MADAGASCAR	134.7	27.4	20.4	41.4	30.7	20.5	15.2	6.4	4.8	0.0	0.0	38.9	28.9
INSULAR AFRICA	**134.7**	**27.4**	**20.4**	**41.4**	**30.7**	**20.5**	**15.2**	**6.4**	**4.8**	**0.0**	**0.0**	**38.9**	**28.9**
TOTAL	**4100.3**	**471.1**	**11.5**	**2246.0**	**54.8**	**767.5**	**18.7**	**316.5**	**7.7**	**10.2**	**0.3**	**288.9**	**7.0**

Table 8b: Annual deforestation during 1981-1990 by forest formations

REGION: ASIA AND THE PACIFIC **YEAR**: 1990

Country	**Annual deforestation 1981-1990**												
	Total	**Tropical rain forest zone**		**Moist deciduous forest zone**		**Dry deciduous forest zone**		**Very dry forest zone**		**Desert zone (cold/hot)**		**Hill and montane zone**	
	000 ha	**000 ha**	**%**	**000 ha**	**%**	**000 ha**	**%**	**000 ha**	**%**	**000 ha**	**%**	**000 ha**	**%**
BANGLADESH	37.6	32.3	86.1	5.2	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BHUTAN	16.4	1.0	6.3	0.0	0.0	0.0	0.0	0.0	0.0	2.4	14.3	13.1	79.4
INDIA	339.0	49.5	14.6	37.8	11.2	214.1	63.2	0.0	0.0	2.1	0.6	35.5	10.5
NEPAL	54.5	3.9	7.2	8.3	15.2	0.2	0.4	0.0	0.0	9.1	16.6	33.0	60.6
PAKISTAN	76.7	0.0	0.0	0.5	0.6	0.2	0.2	1.5	2.0	15.7	20.5	58.8	76.7
SRI LANKA	26.9	1.6	6.0	10.1	37.3	15.2	56.5	0.0	0.0	0.0	0.0	0.0	0.1
SOUTH ASIA	**551.1**	**88.4**	**16.0**	**61.8**	**11.2**	**229.7**	**41.7**	**1.5**	**0.3**	**29.2**	**5.3**	**140.4**	**25.5**
CAMBODIA	131.4	18.3	13.9	39.0	29.7	73.2	55.7	0.0	0.0	0.0	0.0	1.0	0.8
LAOS	129.4	39.6	30.6	42.7	33.0	20.6	15.9	0.0	0.0	0.0	0.0	26.5	20.5
MYANMAR	400.6	161.6	40.3	169.7	42.4	4.2	1.1	0.0	0.0	0.3	0.1	64.7	16.1
THAILAND	515.3	150.8	29.3	195.8	38.0	122.3	23.7	0.0	0.0	0.0	0.0	46.3	9.0
VIETNAM	137.0	47.7	34.8	55.7	40.7	15.7	11.4	0.0	0.0	0.0	0.0	17.9	13.0
CONTINENTAL S.E. ASIA	**1313.7**	**418.0**	**31.8**	**502.9**	**38.3**	**236.0**	**18.0**	**0.0**	**0.0**	**0.3**	**0.0**	**156.4**	**11.9**
BRUNEI	1.8	1.8	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INDONESIA	1 212.0	1025.5	84.7	37.6	3.1	0.7	0.1	0.0	0.0	0.3	0.0	147.3	12.2
MALAYSIA	396.3	368.9	93.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.3	6.9
PHILIPPINES	316.0	168.3	53.2	52.0	16.5	0.0	0.0	0.0	0.0	0.0	0.0	95.8	30.3
SINGAPORE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INSULAR S.E. ASIA	**1926.1**	**1564.5**	**81.2**	**89.6**	**4.7**	**0.7**	**0.0**	**0.0**	**0.0**	**0.3**	**0.0**	**270.3**	**14.0**
PAPUA NEW GUINEA	113.0	91.2	81.5	2.2	2.0	1.3	1.2	0.0	0.0	0.6	0.5	16.9	14.9
PACIFIC	**113.0**	**91.2**	**81.5**	**2.2**	**2.0**	**1.3**	**1.2**	**0.0**	**0.0**	**0.6**	**0.5**	**16.9**	**14.9**
TOTAL	**3903.9**	**2162.1**	**55.4**	**656.5**	**16.8**	**467.7**	**12.0**	**1.5**	**0.0**	**30.4**	**0.8**	**583.7**	**15.0**

Table 8c: Annual deforestation during 1981-1990 by forest formations

REGION: LATIN AMERICA AND THE CARIBBEAN **YEAR**: 1990

Country	Annual deforestation 1981-1990												
	Total	Tropical rain forest zone		Moist deciduous forest zone		Dry deciduous forest zone		Very dry forest zone		Desert zone (cold/hot)		Hill and Montane zone	
		000 ha	%	000 ha	%	000 ha	%	000 ha	%	000 ha	%	000 ha	%
COSTA RICA	49.6	21.7	43.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.9	56.2
EL SALVADOR	3.1	0.8	26.4	0.3	9.9	0.0	0.0	0.0	0.0	0.0	0.0	2.0	63.7
GUATEMALA	81.3	48.9	60.2	31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.6
HONDURAS	111.6	31.2	27.9	10.6	9.5	0.0	0.0	0.0	0.0	0.0	0.0	69.8	62.6
MEXICO	678.0	27.7	4.1	198.1	29.2	29.6	4.4	16.3	2.4	34.5	5.1	371.9	54.9
NICARAGUA	124.0	76.6	61.7	7.2	5.8	0.0	0.0	0.0	0.0	0.0	0.0	40.3	32.5
PANAMA	64.4	33.5	52.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	30.8	47.8
CENTRAL AMERICA	**1 112.0**	**240.3**	**21.6**	**247.3**	**54.6**	**29.6**	**2.7**	**16.3**	**1.5**	**34.5**	**3.1**	**544.0**	**48.9**
ANTIGUA\BARBUDA	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BAHAMAS	4.5	0.0	0.0	3.0	66.8	1.1	25.5	0.1	2.4	0.1	1.9	0.2	3.4
BELIZE	5.0	4.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CUBA	17.3	1.1	6.6	12.6	72.7	0.0	0.1	0.0	0.0	0.0	0.0	3.6	20.5
DOMINICA	0.3	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DOMINICAN REP	35.1	11.1	31.6	8.9	25.4	0.0	0.0	0.0	0.0	0.0	0.0	15.1	43.0
FRENCH GUYANA	0.3	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRENADA	-0.2	0.0	0.0	-0.2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GUADELOUPE	0.3	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GUYANA	18.0	0.0	0.0	3.1	99.8	0.0	0.0	0.0	0.0	0.0	0.0	1.9	10.4
HAITI	1.5	0.3	19.4	0.6	37.7	0.0	0.1	0.0	0.0	0.0	0.0	0.6	42.8
JAMAICA	26.8	13.7	51.1	12.7	47.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.4
MARTINIQUE	0.2	0.2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PUERTO RICO	-4.2	-0.7	15.4	-2.0	47.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.6	37.6
ST. KITTS\NEVIS	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ST. LUCIA	0.3	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ST. VINCENT	0.3	0.2	98.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURINAME	12.7	9.9	77.5	2.9	22.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRINIDAD\TOBAGO	3.7	3.7	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CARIBBEAN	**121.8**	**58.8**	**48.2**	**41.6**	**34.2**	**1.2**	**1.0**	**0.0**	**0.1**	**0.1**	**0.1**	**23.2**	**19.1**
BOLIVIA	624.7	0.0	0.0	441.1	70.6	91.6	14.7	0.0	0.0	0.1	0.0	92.0	14.7
BRAZIL	3 670.9	1 012.6	27.6	1 705.9	46.5	312.6	8.5	0.0	0.0	0.0	0.0	639.9	17.4
COLOMBIA	367.0	222.7	60.7	95.2	25.9	0.4	0.1	0.0	0.0	0.0	0.0	48.7	13.3
ECUADOR	238.0	142.3	59.8	33.2	13.9	0.9	0.4	0.0	0.0	0.0	0.0	61.7	25.9
PARAGUAY	402.5	0.0	0.0	248 7	61.8	151.1	37.5	0.0	0.0	0.0	0.0	2.7	0.7
PERU	271 2	114.3	42.1	38.1	14.0	0.4	0.1	7.0	2.6	4.7	1.7	106.8	39.4
VENEZUELA	599.0	147.2	24.6	337.2	56.3	10.5	1.7	0.4	0.1	0.0	0.0	103.7	17.3
S.AMERICA	**6 173.5**	**1 639.1**	**26.6**	**2 899.4**	**47.0**	**567.5**	**9.2**	**7.4**	**0.1**	**4.8**	**0.1**	**1 055.3**	**17.1**
TOTAL	**7 407.3**	**1 938.1**	**26.2**	**3 188.4**	**43.0**	**598.3**	**8.1**	**23.7**	**0.3**	**39.4**	**0.5**	**1 620.0**	**21.9**
GRAND TOTAL	**15 411.4**	**4 545.1**	**29.5**	**6 084.5**	**39.5**	**1 833.5**	**11.9**	**341.7**	**2.2**	**82.4**	**0.5**	**2 523.8**	**16.4**

Notes: - numbers may not tally due to rounding
- ε indicates a very small value

The estimates of forest cover area and changes by forest formation are derived by integrating FORIS database with ecofloristic zone and vegetation maps, computerised at 1:5 million scale, for use at subregional, regional and global levels. This fact may be kept in view while making use of country level areas.

ABSTRACT OF TECHNICAL REPORTS AND IMPORTANT FIELD DOCUMENTS ON WHICH CONCLUSIONS AND RECOMMENDATIONS ARE BASED

1. PROJECT OVERVIEW - Documents of general nature on the Project

Report on the Expert Consultation (May 1990) FRA 1990 Project

This report contains a review of the Project methodology by the experts and their recommendations, with particular reference to continuous forest inventory design and expansion of the Project activities related to environmental function of forests.

Problems Associated with Estimations of Deforestation and Proposed Methodology for the Project, Background Paper 1 (May 1990) FRA 1990 Project

This short report analyses the problems involved in assessment of deforestation based on existing data and highlights the need for continuous forest monitoring based on remote sensing.

Report of the In-depth Review of the Forest Resources Assessment 1990 Project (April 1992, in English and French) Mission report

This report contains a critical review of the Project's performance covering all objectives, activities and outputs of the Project follow-up.

2. DESIGN I - Modelling Approach

2.1 Compilation of existing information

Guidelines for Assessment based on Existing Survey Data (July 1991, in English, French, Spanish) FRA 1990 Project

These guidelines provide data definition and their classification together with instructions for collection and coding of data in a tabular format.

2.2 Data processing

Forest Resource Information System (FORIS) User Guide

Guide to GIS Databases of the Forest Resources Assessment 1990 Project (June 1991) FRA 1990 Project

The above publications provide an overview of all Project databases, both statistical and spatial.

2.3 Modelling

Estimating and Projecting Forest Area at Global and Local Level: a step forward (November 1990) R. Scotti, FRA 1990 Project

This is an important report providing an in-depth discussion of the Project model.

3. DESIGN II - Remote Sensing based Forest Resources Assessment

3.1 Application of Remote Sensing

Methods and Procedures for Assessment of Tropical Forest Area and Change using High Resolution Satellite Data (October 1990) FRA 1990 Project

This document was the first overview of problems involved in, and suggested approach to, design of the Project activities related to remote sensing.

Procedure for Interpretation and Compilation of High Resolution Satellite Data for Assessment of Forest Cover State and Change (October 1991) R. Drigo, FRA 1990 Project (in English, French and Spanish)

This is a fundamental document providing detailed guidance on the remote sensing procedure used by the Project.

3.2 The Sample Survey Design

The Sample Survey Design (April 1991) FRA 1990 Project

This publication describes the sample survey design based on remote sensing and the estimated magnitude of sampling error.

Evaluation of the Sample Survey Design of the Forest Resources Assessment 1990 Project (March 1992) Prof. D.R. Pelz, University of Freiburg, Germany

This evaluation of the Project sample survey design was made by IUFRO Group on Biometrics and is very interesting for its in-depth comments.

Recommended Procedures for Analysis of Multi-date Remote Sensing Data of FRA 1990 Project (1992) Ranneby, Swedish Royal College of Forestry, Sweden

This document presents statistical formulae for analysis of the Project's remote sensing results.

4. SPECIAL STUDIES AND GIS APPLICATION

Assessment of Tropical Forest Plantation Resource (May 1992) D. Pandey, Swedish University of Agricultural Sciences, Sweden

This document presents the findings of plantation study in the tropics.

Assessing the Conservation Status of the World's Tropical Forest (June 1992) a contribution to FRA 1990 Project by World Conservation Monitoring Centre, United Kingdom

This study presents an assessment of the conservation areas in the tropics.

Status of Plant and Animal Inventories for Protected Areas in the Tropics (May 1992) World Conservation Monitoring Centre, United Kingdom

This study presents the current status of inventories of protected areas and shows that very few protected areas have been researched on species diversity.

PROJECT TEAM

Professional staff	Post	Duration (months)
K.D. Singh	Project Coordinator	42
H. Fischer	APO/Project Officer (forest resources assessment/biometrics)	36
M. Larsson	APO in Thailand (forest resources assessment)	30
A. Hildeman	APO (forest resources assessment)	27
D. DeCoursey	APO (GIS)	24
S. Vanhaeverbeke	APO in Peru (remote sensing)	14
M. Lorenzini	Project Officer (GIS)	27
H. Simons	APO (remote sensing)	17
J. Klaver	Project Officer in Brazil (forest resources assessment)	12
P. Howard	Project Officer (GIS)	2
F. Borry	APO (forest resources appraisal)	4
Support staff		
Y. Caccia-Lupu	Administrative Clerk	30
P. Simonetti	Secretary	22
R. Nasoni-Cianchi	Data entry clerk/Secretary	12
Main consultants		
R. Drigo	Remote sensing	36
A. Marzoli	Data processing	36
G. Mu'Ammar	GIS/Data processing	9
D. Piaggesi	Forest resources assessment	6
Other consultants		
W. Anthony	Follow-up project formulation	2
V.J. LaBau	Rapporteur/forest inventory	2
R. Czaplewski	Statistics	2
K. Waddell	Data processing	2
M. Connelly	Data processing	2
J. Spencer	Resource appraisal	2
W. Disbrow	Resource appraisal	2
C. Fayad	Remote sensing training	2
J. Uhlig	Data processing	4
Technical backstopping		
K. Janz	Senior Forestry Officer (forest resources assessment/monitoring)	

PROJECT NETWORK

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